Proceedings of the 1990 Prairie Tree Nursery Association

Pineland Provincial Nursery
September 10 - 12, 1990

Manitoba
Natural Resources

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FOREWARD

In 1990 the 16th meeting of the Prairie Tree Nursery Association was held.

Papers were presented on container and bareroot seedling culture, outplanting performance and an update of Manitoba's tree improvement program. A tour of Pineland Provincial Forest Nursery in Hadashville was also conducted.

Researchers, operational staff and supplier representatives attended the meeting to exchange ideas and information designed to improve stock quality and reduce production costs.

We would like to thank all of those who participated and contributed to the conference. Special thanks to Richard Lepage, organizing committee chairperson and other staff at Pineland who's hard work made this conference a great success.

Richard Cameron
Nursery Manager
Pineland Provincial Forest Nursery

LAND PREPARATION AT PINELAND NURSERY: SOIL MANAGEMENT PRESCRIPTIONS

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Faculty of Forestry
University of Toronto

Introduction

Soil management practices at Pineland Provincial Tree Nursery are guided by a program of routine soil testing and plant analysis. Soil fertility monitoring normally involves collecting soil samples annually and sending these to the Forest Soils Laboratory at the University of Toronto for chemical analysis. Soil sampling is generally confined to the plow layer (Ap horizon) of the beds since most of the roots of the seedling crop are distributed in this horizon (Armson 1972). The underlying B horizon may also be sampled to serve as reference. Using a core sampler or auger, at least 30 representative soil samples are collected along a random zigzag pattern within a compartment. These samples are thoroughly mixed to form a bulk sample of the entire field, and a sub sample of the composite is sent for laboratory analysis. Together with appropriate calibration information, the analytical results provide the database for formulating fertilizer recommendations for the next growing season.

The aim of the soil testing program is to assist nursery soil management by 1) periodic monitoring of soil nutrient status, 2) diagnosing possible nutrient deficiencies and/or toxicities, and 3) prescribing fertilizer rates to maintain nutrient availability at desirable levels in nursery beds.

Target levels

Prescriptions for fertilizer requirements are based on known relationships between the nutrients status of the specific soil and the upper level of fertilization needed for the crop. Target (critical, guideline, optimum, desirable or recommended) soil nutrient values are usually derived from field calibration trials which determine the concentration of soil nutrients (extracted by a specific analytical method) coincident with maximum growth or yield of the crop. Table 1 shows the target levels (based on similar soil testing methodology) used for bareroot coniferous stock production in three provinces. We are still in the process of verifying the target levels for Pineland Nursery, hence the listed values must be considered preliminary.

General guidelines for controlling acidity in nursery soils consider pH 5.0-6.0 desirable for growing most conifers, and a higher range of pH 6.0-7.0 necessary for most hardwood stock (Tinus 1980). A practical goal of 3.0% organic carbon (or 5.0% organic matter) in soils is assumed sufficient for seedling growth at most northern nurseries (Armson and Sadreika 1979, van den Driessche 1984). Soluble salt concentrations in a number of compartments at Pineland may be

Table 1. Typical target levels associated with similar soil testing for conifer bareroot production in three provincial forest nurseries.

Soil test	Ontario[a]	Manitoba[b]	British Columbia[c]	Analytical method
pH	5.5	5.5	5.5	Water
Organic C (%)	3.0	3.0	3.0	Wet oxidation
P (mg/100g)	30.0	15.0	15.0	Bray 1
K (meq/100g)	0.30	0.35	0.30	1*N* neutral
Ca (meq/100g)	1.50	1.50	8.00	- NH_4Ac
Mg (meq/100g)	0.50	0.50	2.00	leachate

[a] Armson and Sadreika (1979).
[b] Preliminary values.
[c] upper range, van den Driessche (1984).

Table 2. Levels of soil nutrients in the plow layer currently considered desirable for producing bareroot conifer stock at Pinelands Nursery

Soil Nutrient	Levels in the soil				
	meq/100 g	mg/100 g	ppm[b]	pp2m	kg/ha[c]
Avail. P	-	15.0	150	300	300
Ex K^+	0.35	13.7[a]	137	274	274
Ex Ca^{++}	1.50	30.0[a]	300	600	600
Ex Mg^{++}	0.50	6.1[a]	61	122	122

[a] to convert meq to mg multiply by equivalent wt (equivalent wt = atomic wt/valance).
[b] to convert mg/100 g to ppm, multiply by 10
[c] assuming plow layer weighs 2 million kg/ha.

excessively high. At present, the tolerance levels for conifers derived by Carter (1980) are used as management guides to intensify irrigation to promote leaching.

Verification of target values

Target levels may vary with location (Table 1), depending on climate, species, soil conditions and/or cultural systems. It is important therefore that their accuracy be periodically verified. Fig. 1 shows that at the Thunder Bay nursery optimum growth of seedlings and greenhouse transplants occurred at about 50 mg/100g available P rather than the 30 mg P/100g target level used for Ontario. Toxicity may be expected at soil P levels exceeding 75 mg/100g. Verification studies with Kemptville nursery soils (Fig. 2) have confirmed that maximum growth of hybrid poplar is at a higher soil pH (6.5) than normally associated with conifer culture.

Determination of target levels may also be complicated by nutrient interactions or nutrient imbalance occurring in soils or plants. A series of fertilization trials in hybrid poplar stool beds at Kemptville Nursery (Teng and Timmer 1990a, b, Timmer and Teng 1990) have demonstrated that maximum growth is achieved at 5-10 mg P/100g (Fig. 3, cluster A), however, at higher P levels productivity was increased when supplemented with Zn alone (cluster C), or with Zn and Cu combined (cluster E), because of suspected phophorous-induced micronutrient deficiencies in susceptible clones.

The plow layer as a reference unit

Since nursery seedlings derive their nutrients mainly from the rooting zone of the soil, rates of fertilizer application are calculated on the basis of the amount of nutrients needed to raise the soil plow layer to desired fertility levels. Hence, the "hectare-furrow-slice" (or "acre-furrow-slice") is used as a reference unit for these calculations. The weight of a hectare-furrow-slice depends on its depth as well as its bulk density. Generally plow depths in nurseries range from 15 to 20 cm. Combining the greater depth with a common bulk density of 1.0 g/cm^3 (and remembering that density = mass/volume), the mass of the plow layer can be calculated as:

$$\text{Weight of plow layer} = 1.0\ \text{g/cm}^3 \times \frac{20\ \text{cm} \times (100\ \text{cm/m})^2 \times 10{,}000\ \text{m}^2/\text{ha}}{1{,}000\ \text{g/kg}}$$

$$= 2{,}000{,}000\ \text{kg/ha} = 2\ \text{million kg/ha}$$

The same result can be obtained by assuming a shallower depth but a higher bulk density, such as 15 cm and 1.33 g/cm^3. A hectare-furrow-slice is, therefore, often assumed to weigh 2 million kg as a reasonable estimate. Since pounds per acre (the comparable unit in the Imperial system) is approximately the same as kilograms per hectare, the two units are often considered equal, and an acre-furrow-slice is taken as weight 2 million lb. If a more accurate conversion is needed, the factor 1.0 lb/ac = 1.12 kg/ha may be used. It must be remembered that the 2 million value is an approximation which may often be off by 10-20 percent in either system.

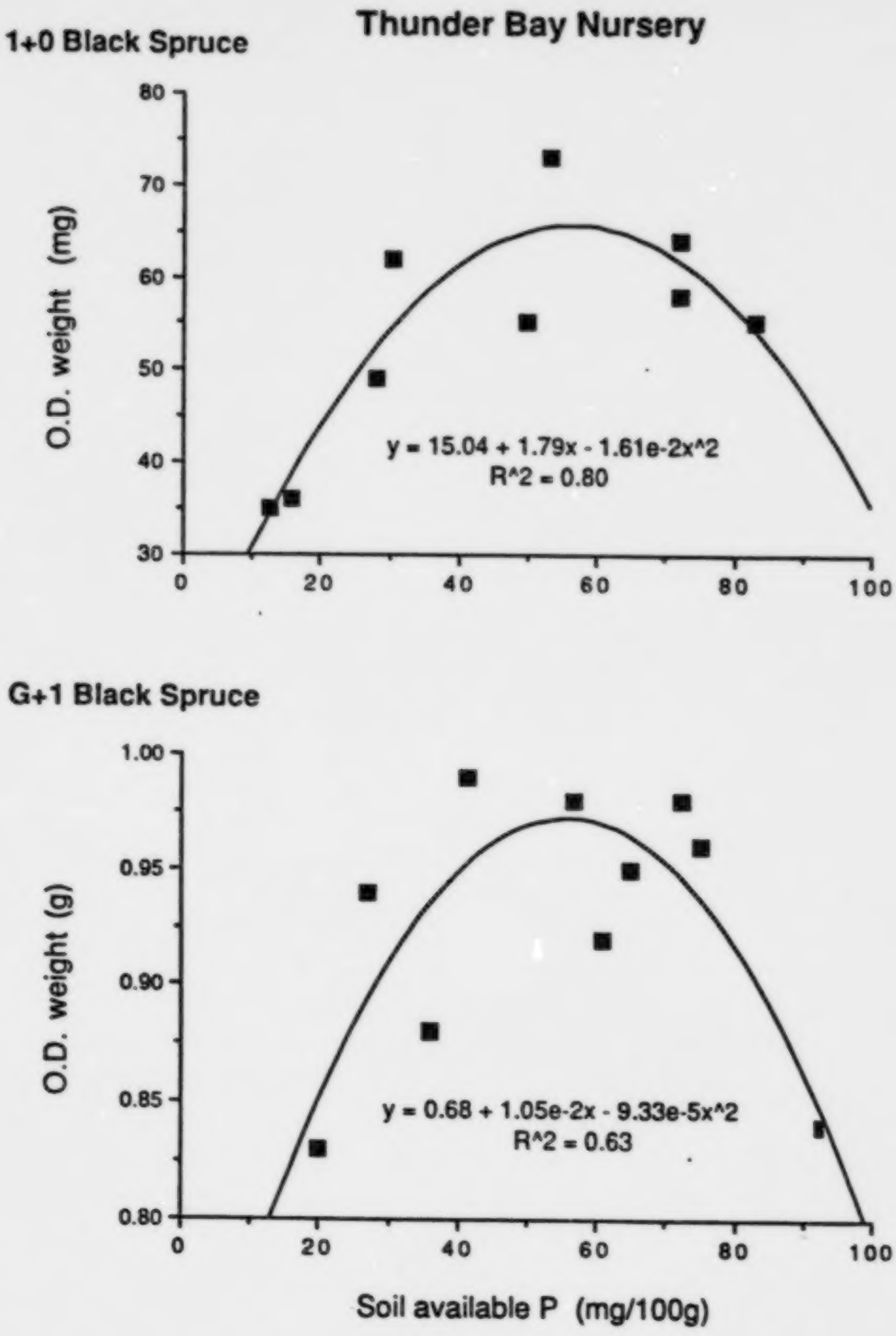


Fig. 1. Dry matter production of black spruce seedlings (1+0) and greenhouse transplants (G+1) grown at increasing levels of soil available P at the Thunder Bay nursery. (adapted from Palcic 1987, Palcic and Davies 1988).

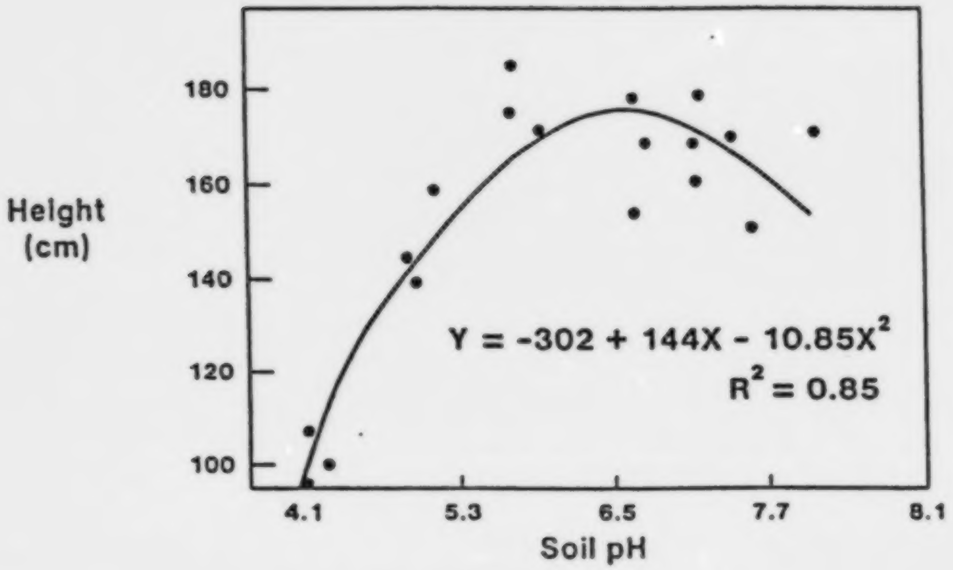


Fig. 2. Height of 20 week-old hybrid poplar cuttings (clone DTAC-32) growing at varying pH of a Kemptville nursery soil altered by liming and sulfur treatments (from Timmer 1985).

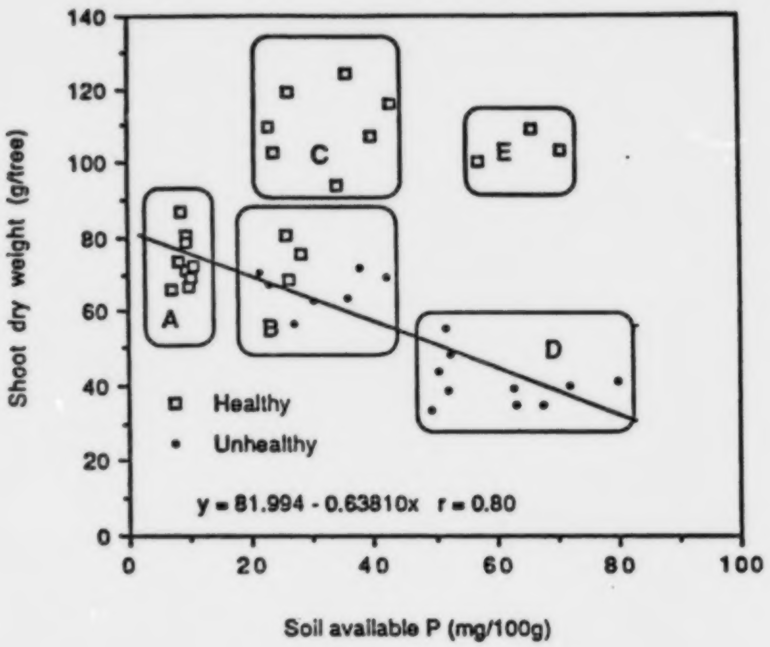


Fig. 3. Relationship between shoot dry weight of hybrid poplar (*P.* x *euramericana*) clone DN17 and soil available P before planting. Cluster A received no P; cluster B was treated with P at 288 (1/2P) to 576 (1P) kg/ha; the difference between cluster C and B was supplementation with Zn; cluster D received P at 1152 kg/ha (2P) with or without Zn. Foliar Cu spray was applied to cluster E fertilized with 2P and Zn. The regression consists of treatments free of Zn and Cu.

Converting soil analyses to field use

Despite being an approximation, the 2 million kg/ha or lb/ac value is widely used for converting laboratory data to field use. Soil analysis results are usually reported as concentrations in parts per million (ppm), milligrams per 100 grams (mg/100g), or milliequivalents per 100 grams (meq/100g). Multiplication by 2 converts ppm to pp2m (parts per 2 million) for use on either a kg/ha or lb/ac basis. Similarly, multiplying 20 times an equivalent weight converts meq/100 g to pp2m or kg/ha. Hence, soil analyses expressed in concentration values can be easily converted to absolute quantities in the plow layer utilizing the appropriate conversion factors, as shown in Table 2. It can be seen that the various amounts of macronutrients required for producing a satisfactory conifer crop in a hectare-furrow-slice at Pineland nursery are 300, 274, 600 and 122 kg/ha of P, K, Ca and Mg, respectively.

Fertilizer prescriptions

Fertilizer prescriptions relate current nutrient status of the soil (as determined by soil tests) against optimum target levels. The amount of elemental fertilizer required for maximum growth is the difference (in kg/ha) between the optimum level (Table 2) and that of the soil sample representing the compartment. For example, a sample recording 5 mg/100 g of available P would represent 100 kg P/ha in the plow layer, which would require (300-100) or 200 kg/ha of fertilizer P to raise its concentration to the optimum. A compartment with 0.1 meq/100 g (or 78 kg/ha) exchangeable K in the plow layer would need (274-78) or 196 kg K/ha to bring soil K status to target level.

These calculations assume that the prescribed rate of fertilizer application is completely effective (i.e. 100% efficient) in raising soil nutrients to the target level. Appropriate factors compensating for excessive leaching and/or substantial fixation of added nutrients on specific soils, or under particular management systems, would need to be incorporated in the calculation to adjust for such losses. For instance, prescriptions for P fertilizer at Thunder Bay should be much higher than those at Orono because of differences in the fixation capacities of the soils. Under laboratory incubation the degree of phosphate-fixation was much higher for a Thunder Bay soil compared to an Orono soil (Fig. 4). Fertilization trials following incubation studies have confirmed these interpretations (Palcic 1987).

Fertilizer efficiencies for P and K amendments have recently been derived at Pineland and Dryden nurseries. At relative low initial soil levels, P and K applications were 35% and 87% effective in raising soil test values, respectively (Fig. 5). The efficiency is expected to improve once fixation capacities have been saturated, and when soils become closer to target levels.

Fertilizer amounts

It is important to note that the fertilizer quantities prescribed for raising soil nutrient status to target are expressed in elemental form (such as P of K), not in the oxide form (such as P_2O_5 or K_2O)

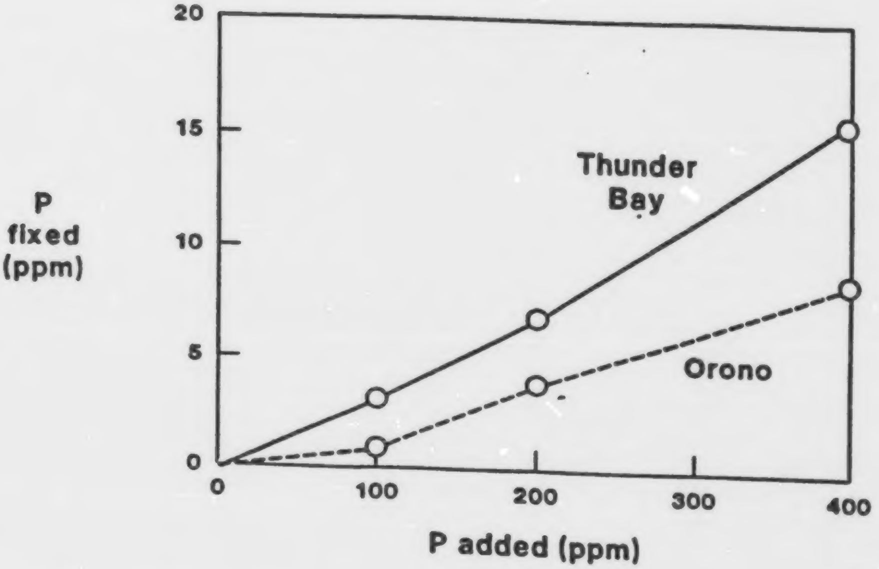
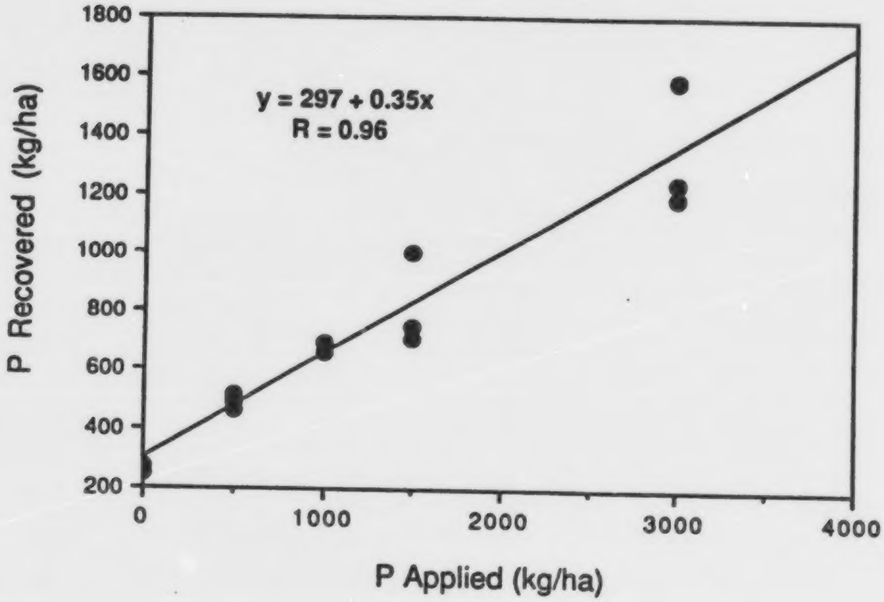


Fig. 4. Comparative phosphate fixation capacities of Thunder Bay and Orono nursery soils. Amount of P fixed is the difference between P added and that extracted after 72 h incubation at 30°C.



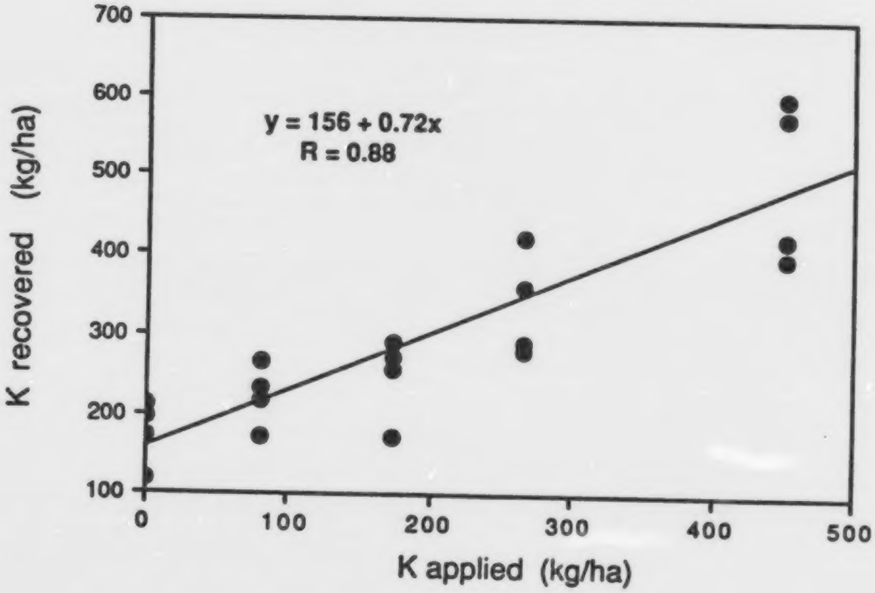


Fig. 5. Relationship between the amount of elemental fertilizer applied and that recovered one growing season after application. Phosphorous at Pineland nursery (above) and potassium at Dryden nursery (below).

usually reported on the fertilizer bag. Fertilizer analysis can be converted from oxide to elemental form using a multiplier of 0.436 for P, and 0.83 for K. These conversions will simplify calculations for the actual amount of fertilizer material needed in the field, since analysis vary with brand, source, or type of fertilizer used at the nursery.

Although there are several chemical means for evaluating both the amount and form of N in the soil, these tests have limited success in predicting plant available N over the growing season. Hence, recommendations for N fertilizer applications are not usually based on soil analysis. Instead, rates and frequency of top dressing for N are guided by growth development and nutrient demand (foliar nutrient composition) of the seedlings, and are in some cases scheduled on a cumulative degree day basis (Armson and Sadreika 1979). There is an increasing trend to apply both N and P (as ammonium phosphates) in top dressings, rather than N only fertilizers.

Soil pH control and organic matter

Calculations for ameliorating soil pH and organic matter to desired levels in nursery beds make use of empirically derived adjustment factors. Mullin's (1964) work with Orono soils has shown that between the range of pH 5.0-7.5, powdered sulfur incorporated at 112 kg/ha will reduce soil pH by 0.1 unit. The adjustment factor for a compartment at Pineland nursery is 182 kg/ha (Fig. 6). This factor will vary of course with soils of different buffering capacity.

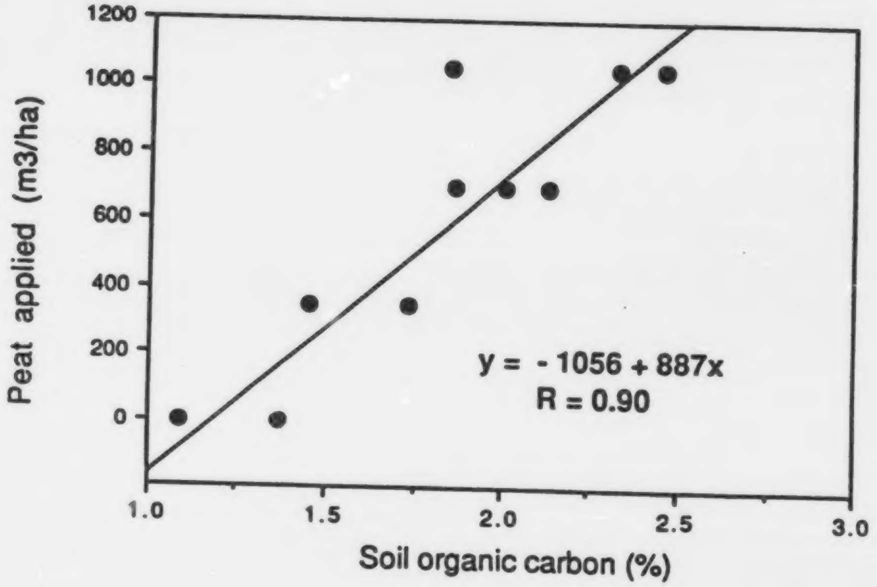
Early experience with peat additions in Ontario nurseries has led to the following adjustment factor: 24 m^3/ha of fibrous peat will normally increase soil organic C by 0.1% (Armson and Sadreika 1979). Obviously this value changes with different types of organic material and/or rates of subsequent decomposition. More recent calibrations of know additions of peat to seedbeds have shown that this adjustment factor is too low for most of the peat sources available at nurseries. At Pineland about 90m^3/ha of horticultural grade peat is required to raise organic C status by 0.1% (Fig. 6).

Plant tissue analysis

The effectiveness of fertilizer additions and soil amendments for land preparation treatments and top-dressing practices at Pineland nursery is monitored annually by a regular program of foliar analysis of growing stock in all fields at the end of the growing season. Until we have developed local standards, foliar nutrient concentrations are compared with working ranges derived for similar stock types in Ontario by Armson and Sadreika (1979).

Research support

The reliability of a soil testing program for planting stock production is highly dependent on research support to develop analytical techniques, refine interpretations, verify prescriptions and follow seedling outplanting performance. This work is undertaken cooperatively with nursery staff and graduate students of the Faculty of Forestry, and involves demonstration trials, field plots, greenhouse studies and laboratory experiments. We have calibrated methods used for assessing growing media quality (Folk and Timmer 1987), soil nutrient status



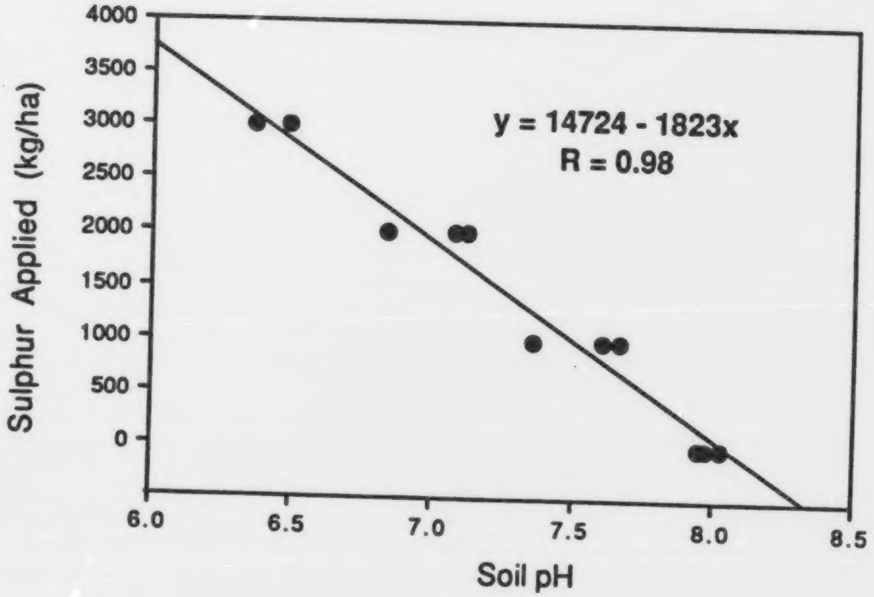


Fig. 6. Effect of increasing peat additions on soil organic carbon status of the soil (above). Effect of increasing sulphur applications on soil pH (below). Pineland nursery.

(Timmer and Parton 1984) and irrigation requirements (Timmer and Armstrong 1989) for container production systems, and developed improved diagnostic techniques for interpreting foliar nutrient analyses (Timmer and Armstrong 1987a, Timmer 1990b). New fertilization practices, such as exponential fertilization (Timmer and Armstrong 1987b), steady-state nutrient preconditioning (Timmer et al 1991),and nutrient loading (Timmer and Munson 1991) have shown promise in reducing planting shock and increasing outplanting performance. We have promoted the concept of site-specific seedling production in the framework of regional Forest Ecosystem Classification systems (Munson and Timmer 1989a, b, 1990, 1991). These studies form an integral part of the Forest Soils Laboratory, and are relevant to current management practices dealing with nursery soils and intensive planting stock production.

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Wesbrook

DEVELOPMENT OF OPERATIONAL LAND PREPARATION PROGRAM AT PINELAND NURSERY

Wendy Kozmak
Bareroot Supervisor

The University of Toronto is under contract to conduct soil and foliar analysis for Pineland Nursery, as well as provide recommendations for land preparation. Dr. Timmer has already discussed how he derived his recommendations, so my paper will show these recommendations are applied.

Each field is sampled in late September or early October. Samples are sent to the University of Toronto forestry soils lab, and the results and recommendations are back to us by the end of November. This allows us time to draw up the land prep program for the coming year and prepare requisitions for materials. An example of the recommendations is shown in Figure 1. The actual soil levels are on the left side and recommendations are on the right. I will be taking one field from this report (Lab No. 21, Soil Horizon A, Comp No. 35) and developing the land preparation program to illustrate the procedure.

1. Organic Carbon (O.C.)

Soil level - 1.39%
Target* - 3.00% *Target levels are shown at the bottom of figure 1.
Recommendation: 1771 m^3/ha of peat.

Considerations: The recommended rate of peat would bring the soil O.C. to 3.0%, however, it is not possible to incorporate this large an amount of peat at one time. The maximum rate we can incorporate is 350 m^3/ha, so this would be the application rate for this field.

2. pH

Soil level: 6.41
Target: 5.5
Recommendation: 1720 kg/ha

Considerations: The maximum application rate is 2000 kg/ha. However, most of our fields are quite variable in pH, and a field with an average pH of 6.5 may have actual ph's ranging from 4.5 - 7.5. As a result applying high rates of sulphur causes excessively low pH values. Any field when there is a wide variation in pH's we are starting to cut back application rates to approximately 1000 kg/ha.

3. Phosphorus

Soil level: 8.33 mg/100 g
Target: 15.00 mg/100 g
Recommendation: 427 kg/ha elemental P
= 2100 kg/ha 0-46-0

4. Potassium

Soil level: 0.12 meq/100 g
Target: 0.35 meq/100 g
Recommendation: 609 kg/ha elemental K
= 1468 kg kg/ha 0-0-50

Once all the recommendations are determined, the previous history of the field is reviewed. All land preparation records and soil analysis data is stored on spreadsheets. The relationship between additions of amendments and subsequent changes in soil levels can be graphed quite easily. An example is shown in figure 2. The upper graph shows pH, organic carbon and phosphorus levels in field 7, over 4 different sampling times from March '87 to September '89. By comparing the amount of elemental phosphorus added in the summer of '88 to the use in soil phosphorus, an efficiency factor can be determined that is specific to field 7. As our data base grows we will be able to develop efficiency factors specific to each field, for each type of soil amendment, and use these efficiency factors to adjust the recommendations we receive from the University of Toronto.

The recommendations we receive from the University of Toronto are meant to be used as a guideline. The final land preparation program has to be tailor made to fit the characteristics of each field. At the start our contract with the University of Toronto, we didn't have the ability to do this, however, with more experience, and more data to work from, we are getting closer to the results we want.

Forest ..ls Laboratory
Faculty of Forestry, U of T
33 Willcocks Street
Toronto, Ont., M5S 3B3

Soil Analysis ..eport

Pinelands PFN 1989

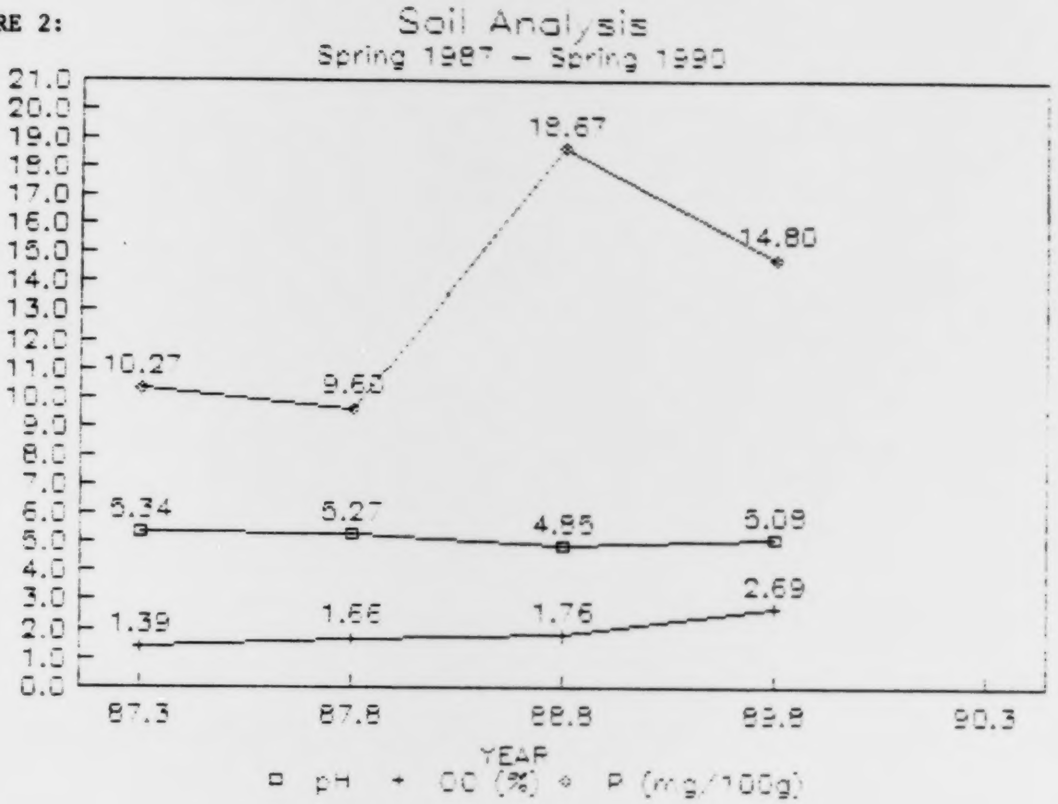
Tel: (416)978-3329 Fax: (416)978-3834
Date:
Purchase Order No.:
Work Order No.:

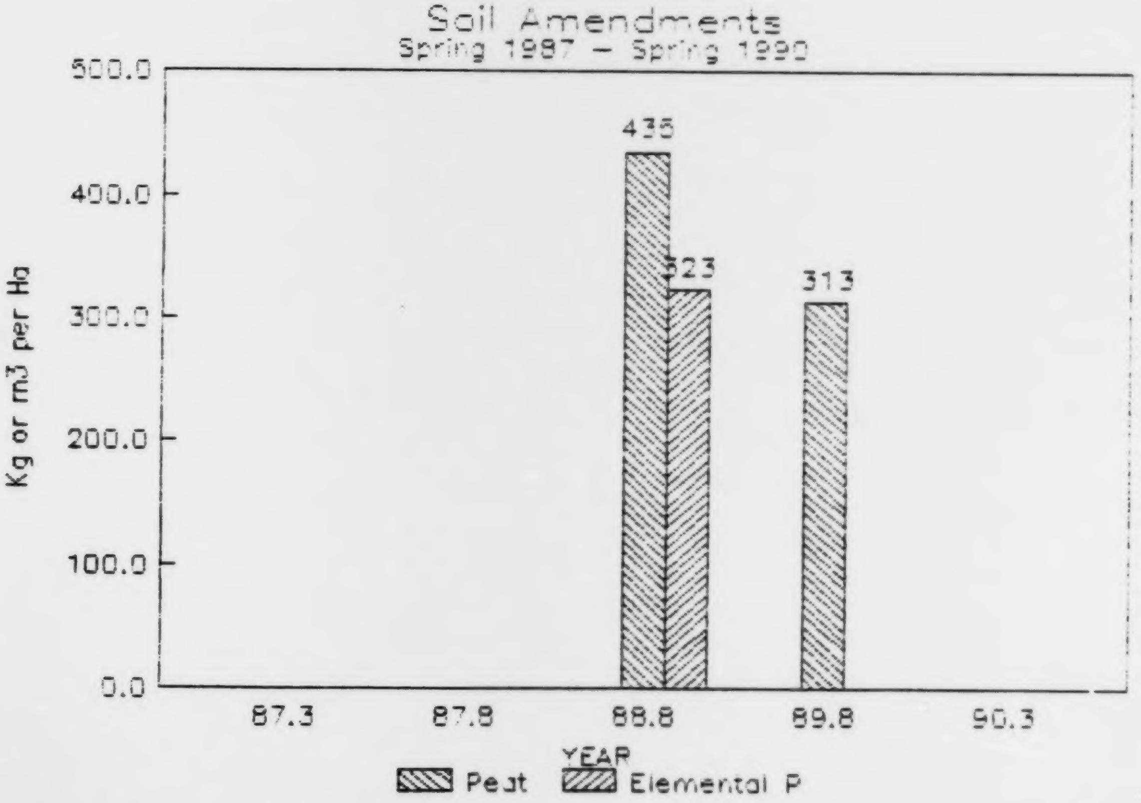
Sample Data			Soil Analyses							Fertilizer Recommendations							Remarks
Lab No.	Soil Hor.	Comp. No./[illegible]	pH	OC (%)	N (%)	avail P mg/100g	ex K ---meq/100g---	ex Ca	ex Mg	Sulph ---kg/ha---	Lime	Peat m3/ha	P -----kg element/ha	K	Ca	Mg	
15	A	32	7.67	1.92		1.67	0.10	17.89	3.21	4101	na	1188	853	662	na	na	Shelterbelt
16	B		7.83	0.88		1.07	0.08	20.91	3.01								trees
17	A	33	7.07	2.57		9.80	0.13	10.71	2.13	2967	na	473	333	582	na	na	low lying,
18	B		7.17	1.31		5.80	0.14	10.61	2.49								patchy
19	A	34	7.19	1.75		18.67	0.09	19.87	1.77	3194	na	1375	na	688	na	na	
20	B		7.40	1.07		4.87	0.06	20.97	1.29								
21	A	35	6.41	1.39		8.33	0.12	5.60	0.95	1720	na	1771	427	609	na	na	
22	B		7.61	1.15		5.87	0.09	12.05	1.16								
23	A	36	5.73	2.62		18.27	0.11	5.74	1.08	na	na	418	na	635	na	na	TDT#1 here
24	B		6.97	0.86		10.47	0.11	5.49	0.90								
25	A	37	6.19	2.02		26.13	0.14	11.20	2.11	1304	na	1078	na	556	na	na	TDT#8 here
26	B		7.41	1.09		8.00	0.09	14.81	1.93								
27	A	38	6.61	1.65		29.00	0.12	12.68	1.34	2098	na	1485	na	609	na	na	TDT #10 soil
28	B		7.66	1.41		6.27	0.07	18.24	1.26								
29	A	39	6.41	2.51		12.27	0.10	10.74	1.08	1720	na	539	175	662	na	na	
30	B		7.43	1.10		11.73	0.09	20.54	1.44								
31	A	40	7.87	2.72		3.53	0.09	14.67	1.52	4479	na	308	734	688	na	na	
32	B		7.78	1.13		1.27	0.07	22.41	1.54								
Target Levels:			5-6	3.00		15.00	0.35	1.50	0.50	Ref: U of T/Manitoba Calibration Tests							Page 3/3

FIGURE 1:

FIELD 7 PROFILE

FIGURE 2:





OVERWINTERING CONTAINER STOCK AT PINELAND PROVINCIAL FOREST NURSERY

Richard Lepage
Pineland Provincial Forest Nursery

Introduction

Overwintering container stock out-of-doors is a risky undertaking especially in the prairie provinces. Sufficient snowfall to protect stock from desiccating winds and root damaging cold temperatures is often not reliable. When adequate snow cover is present there are still concerns of losses to snow mold or frost damage to flushed stock in the spring.

Stock Production

A variety of species, sowing dates and containers are used to meet the regeneration needs of the province. *Table 1 provides a summary of the overwinter container stock produced at the nursery.

Jack pine is grown until early August when it is moved outdoors for hardening. It is lifted in late October or early November and placed into frozen storage.

Black and white spruce is grown until August or September when bud initiation occurs naturally or is induced. Seedlings are then hardened using the extended greenhouse culture technique (Colombo 1983). A number of different criteria are used to determine when stock is ready for lifting and are listed below:

- two successive frost hardiness tests at -15°C with an index of injury less than 5%.
- one frost hardiness test at -40°C with an index of injury less than 5%.
- eight weeks from the date of 100% bud initiation.
- two weeks of root hardening.
- five consecutive nights with media temperatures between 0 and 5°C.
- minimal root activity through visual examination.

Lifting, Grading and Packaging

Stock is lifted, graded and packaged in the packing shed. Seedlings are placed on conveyors in pyramid shaped stacks of 25 seedlings. Modified food wrappers are used to wrap the bundles. The bundles are then placed in a cardboard box lined with a 2 mil. opaque poly bag. A total of 600 seedlings (multipot 1 and 2) are contained within a box which is 40cm in length, width and height. Following is the approximate cost per thousand seedlings for the entire process:

Labour	$17.00
Wrapper	$ 0.35
Boxes	$ 1.75
Bags	$ 0.40
	$19.50

Summary

Avoiding environmental concerns and ensuring stock availability the following spring are not the only advantages of frozen storage.

Since stock is lifted and graded in the autumn, containers are available for use immediately the following year thereby reducing tray inventories. When grading, stock can be sorted to better meet specific planting sites, if required ie. larger stock for more competitive sites.

Lifting and packaging in the fall takes advantage of the slow period at the nursery as compared to the spring when the shipping of overwintered container stock would otherwise occur. Stock inventory is precise and shipping costs are greatly lowered because of reduced handling and the ability to ship larger quantities per load.

Frozen storage is also conducive to snow caching of stock on more inaccessible planting sites, a practice attempted for the first time in Manitoba this past year with favourable results.

Finally, frozen stored stock is extremely stress resistant and well able to cope with the rigors of handling and planting as compared to stock in the container that may have flushed. Having stock in frozen storage also enables extending the spring planting season.

*Table 1

Overwinter Container Stock Available At Pineland Provincial Forest Nursery

			Container		Stock Parameters					
Species	Growing Structure	Sowing Date	Type	Volume (cc)	Height (cm)	Diameter (mm)	ODW (mg)	Shoot:Root Ratio	Primordia	*R.G.C.
Black Spruce	Tunnel	May 1	2/67	65	16	1.8	1000	3:1	185	3.5–4
	Tunnel	Apr. 25	6/45	110	18	2.1	1500	2.5:1	260	4–5
	Greenhouse	June 1	1/67	57	14	1.8	750	3:1	150	3.5–4
White Spruce	Greenhouse	June 1	2/67	65	14	1.7	800	3.5:1	125	3.5–4
Jack Pine	Greenhouse	June 5	2/67	65	14	2.1	1100	2.5:1	—	4–5

*Root Growth Capacity using Burdett (1977) index of root growth and a 21 day potting at 25°C Day/22°C Night temperature.

MANITOBA'S TREE IMPROVEMENT PROGRAM

JOHN DOJACK - FORESTER
MANITOBA NATURAL RESOURCES

Three and a half years ago a review was conducted on Manitoba's tree improvement program. Following the review a tree improvement strategy was drafted for the province. The tree improvement strategy identified breeding alternatives, the rationale for the recommended approach and a recommended implementation schedule based on existing resources and funding.

The objective of Manitoba's tree improvement program is to increase the yield and quality of wood produced from plantations through the development of genetically improved planting stock. The program involves selecting a large number of plus trees from across the breeding zones, evaluating the plus trees on uniform test sites and then breeding the best selections to reproduce genetically improved planting stock. Following this first generation program a repeated cycle of selection evaluation and production will occur in subsequent generations.

The review of the existing tree improvement programs illustrated that the jack pine orchards established by Forestry Canada in co-operation with the province were of adequate size to eventually meet 75% of the seed requirements. However, the existing black spruce and white spruce orchards were of sufficient size to meet only 2% of the seed requirements. Therefore, a major effort was required in the black spruce and white spruce tree improvement programs.

With industry playing a key role in forest renewal programs the recommendation was made that new tree improvement programs be established as co-operative efforts with forest industry. This led to the establishment of the Manitoba Tree Improvement Co-operative with the Manitoba Forestry Branch, Abitibi-Price and Repap Manitoba. Two co-operative programs were established through informal Memorandums of Understanding which identified the division of work loads and improved seed from the orchards.

Breeding zones were established across Manitoba for each of the three species; jack pine, black spruce and white spruce. The first phase of the implementation schedule of the tree improvement program keyed in on the primary species for the breeding zones with the largest planting programs. The first step in the programs involved selecting a large number of plus trees from wild stands throughout the breeding zone. Plus trees were selected using ground and aerial crews with up to 60% of the trees selected using helicopters. The use of a helicopter enabled sampling remote populations throughout the breeding zone.

Cones from the plus trees were kept separate by plus tree, the seed from each tree given a family number. Seed was extracted, cleaned and stored at Pineland nursery. All tree improvement crops are produced at Pineland Nursery where they are sown into BC stryoblock 20 containers and grown under high pressure sodium lights for approximately 17 weeks. Two crops are produced per year in the tree improvement facility. Planting stock for family tests are produce as overwinter crops, whereas orchard stock is produced as a current crop. Family tests are sorted into replications using the single tree plot design prior to storing in the freezer units.

Many of the costs associated with the tree improvement program are fixed. for example, the same number of plus trees selections and replications in family tests are required regardless of the size of the seed orchard that they are testing. However, the amount of benefit achieved from the program is not based just on gains but also on the number of trees improved. For this reason breeding zones which have smaller planting programs have a lower cost option recommended for their tree improvement program. For example, with black spruce in planting zones with less than one and a half million seedlings planted per year, a mass selection seed orchard program is recommended. Breeding zones with planting programs over one and a half million seedlings per year have a family test and seedling seed orchard program recommended.

Family test sites are intensively prepared by raking and discing the sites to minimize environmental variation, ensure even spacing within the family tests and improve the accuracy of early test results. All family test sites are prepinned at a 2 meter x 2 meter spacing prior to planting. The family tests are mapped using a husky Hunter Data Logger which enables identifying any errors and subsequently correcting those errors within one day of planting the test. Up to five spares per family will be lined out at the family test site to enable refilling any incorrect or dead seedlings within the first two years of the family test life.

Because of the intensive site preparation it is essential that family test sites have a very well developed duff layer. It is also crucial that site preparation treatments are closely supervised to ensure the treatments are not too severe which would result in the removal of the duff layer entirely. Experience has shown that this can decrease plantation survival from the high nineties to the low sixties.

Intensively cultivating sites and using large healthy planting stock has resulted in average family test plantation survival rates of over 95%. Although these results have been very encouraging we have learned never to beat your chest too early. Survival surveys conducted on the first black spruce family tests which were established over two years ago indicated a survival rate of 97%. However, as a result of severe winter desiccation damage followed by unprecedented heavy rains throughout the spring the survival rate dropped to 50% by June of the following year.

The first black spruce seedling seed orchard was planted in co-operation with Abitibi-Price during June of this year. The orchard is planted at a close 1 meter x 3 meter spacing and will be rogued to the top fifty families based on family test results. The Manitoba Forestry Branch - Repap co-operative black spruce seedling seed orchard will be planted in June of 1991.

The white spruce tree improvement program for breeding zones with planting programs over one million seedlings per year involves collecting cones for open-pollinated family tests and scions for establishing a clonal seed orchard. The family test for the Western Region, white spruce tree improvement program involved four test sites which were fenced to prevent browsing damage. Scions from the plus tree were collected at a later date and grafted at Pineland Nursery for establishing a clonal seed orchard which will be located at Birds Hill Nursery. Due to excessive costs the approach being recommended for white spruce will be revised for the next program. The next program will involve intensively selecting fewer white spruce plus trees and establishing a clonal container seed orchard.

The jack pine tree improvement program, established by Forestry Canada over twenty years ago involved selecting 226 plus trees and establishing four open-pollinated family tests in each of the two breeding zones. Based on the 10 year results of the family tests, controlled crosses were conducted amongst the top 40 ranked families in order to produce pedigreed seed for growing a seed orchard. Pedigreed seed was grown at Pineland Nursery by Forestry Canada staff in large four litre pots to enable establishing a pedigreed seed orchard on August of 1988. Under the Canada Manitoba Forest Renewal Agreement lower cost programs were also established for the Northern and Interlake breeding zones. These programs involved the establishment of mass selection seed orchards. The orchards are established at a close 1 meter x 1 meter spacing to enable their intensive roguing which will leave only the top 10% of the trees to open pollinate. Every 3 to 5 years the orchard will rogued by 50% based on ocular comparisons of two neighbouring trees.

This represents the completion of the first phase of the implementation schedule for the tree improvement program. At the present level of funding all first generation family tests will be established by 1996 and all first generation orchards should be planted by 1998.

PRELIMINARY RESULTS OF INFRA-RED HEATING TRIALS AT CIEARWATER NURSERY

Shane Tornblom
Clearwater Provincial Forest Nursery

BACKGROUND

Clearwater Nursery operates 20 greenhouses. The primary heating system is wood fired under bench forced air. Each furnace produces approximately 320,000 B.T.U. distributed between two greenhouses. In addition, each greenhouse has two supplementary heating systems:

1) A 136,000 B.T.U. electric forced air furnace with a poly tube under the ridgeline and
2) A 192,000 B.T.U. propane forced air unit heater with poly tube along one side of each greenhouse.

These two systems, are switchable for secondary and tertiary back-up heat, but on cold days all three systems are required regularly. Total heat output is approximately 488,000 B.T.U./per greenhouse.

WHY CONVERT HEATING SYSTEMS?

Clearwater Nursery started evaluating options to its existing heating systems because of five primary concerns.

1) The high year round cost resulting from hydro peak demands created in winter.
2) Escalating costs for fuelwood.
3) Maintenance time and costs associated with wood furnace firebox repairs.
4) Workers safety and associated W.C.B. costs.
5) The need to increase seedling production without increasing annual operating budgets.

Several options were considered, including installing large propane furnaces in the headerhouses and hot water boilers. Propane furnaces were eliminated because there was not enough potential decrease in energy costs to justify the capital investment. Since preliminary estimates for hot water boilers indicated a capital cost in excess of one million dollars, other options had to be explored.

As part of the process, infra-red was considered. Growers using this technology indicated several benefits and strong support for this system. Based on information from users, discussions were initiated with distributors in the province. Ultimately two brands were made available for a six-month operational trial, with the option to buy.

H.F. Clark supplied a Co-Ray Vac system consisting of two lengths of pipe running both above and below benches. Each length of pipe had one 80,000 and three 60,000 B.T.U./hr burners with total output of 520,000 B.T.U./hr. Combustion air was internal greenhouse air. H.F. Clark supplied radiant heat shields to minimize potential over heating rear burners.

The competing system was an Ambi-Rad supplied by I.C.G. Ltd. unlike the Co-Ray Vac, this was only an above bench system. It had six 75,000 B.T.U. burners with a total output of 450.000 B.T.U./hr. Combustion air was from the external environment. The Ambi-Rad supplier had to be convinced by us that radiant heat shields were required to minimize potential burning of crops. I.C.G. installed all gas lines, as well as the Ambi-Rad heating system.

The Ambi-Rad was much more difficult to install, since it tended to sag lengthwise and tilt sideways. In addition, initial start-up procedures were more complex. Every time one burner was adjusted all five other burners had to be re-adjusted, due to the system's precise vacuum requirements. Start-up calibration was not a problem with the Co-Ray Vac.

At the same time that heating systems were converted, florescent fixtures were replaced with 6 - 400 watt high pressure sodium lamps for photoperiod control so as to minimize infra-red shadows.

TABLE 1: **RELATIVE COSTS OF TRIAL INFRA RED SYSTEMS**

Heating Systems	Cost ($ x 1000)			
	Infra Red System	Disposables	Gasline Fitting	TOTAL
Co-Ray	11.812		2.3	14.112*
Ambi-Rad	7.969	1225.00		9.194*

*Excludes labour to install systems.

TRIALS

Current crop jack pine was grown in both infra red houses using our standard cultural guidelines and schedules. Two control jack pine crops were grown using our normal heating systems, but these crops started germinating four to ten days earlier. Growth progression (G.P.) was performed bi-weekly from 4 weeks after germination to shipping at approximately 16 weeks. Two over winter black spruce crops were grown from June to late July, but crop reports have not been completed.

Eight measurements of temperature gradients were conducted over a 3-4 day period, in both of the trial houses. These measurements consisted of media temperature, top of media temperature, bottom of media temperature, air temperature and relative humidity level at 4 stations within the greenhouse.

TRIAL #1 Measure the length-wise gradient under burner.

TRIAL #2 Measured the length-wise gradient on the outside table.

TRIAL #3 Measured the gradient between the burners at the cold end of the house.

TRIAL #4 Measured the gradient between the burners at the hot end of the house.

TRIAL #5 Measured the gradient of ½ the width of the greenhouse from outside to the center.

TRIAL #6 Measured the gradient of the entire width between the outside walls.

TRIAL #7 Measured under bench temperature gradients along outside bench.

TRIAL #8 Measured under bench temperature gradients along center bench.

No such trials were conducted in the control greenhouses.

OBSERVATIONS:

Heating trial temperature data was of questionable value since the hygrothermographs record ambient air temperature versus surface temperature. This led to our major concern for (a) finding an appropriate temperature sensor for radiant heat and (b) locating it in the most appropriate location for control. Despite calibration of hygrothermographs prior to the trial, minor differences may have contributed to the problems encountered when data was analyzed for trends or gradients. Media or tissue temperatures may be of greater value than ambient air temperature, since infra red heats mass vs. air. See tables 2 and 3 for relative advantages/disadvantages and acceptability/unacceptability of the two infra red systems.

Table 2: **RELATIVE ADVANTAGES/DISADVANTAGES OF CO-RAY VAC AND AMBI-RAD HEATING SYSTEMS - 1990 Clearwater Nursery TRIAL**

FACTOR	CO-RAY VAC	AMBI-RAD
Mechanical	-intermittent ignition problem on random burners remedied by design modification, -3 try ignition system.	-no known problem
	-no indicator lights	-vacuum and ignition indicator lights burned out.
	-excellent heat shields with potential to add or subtract.	-inadequate factory radiant heat shields.
Heating Capacity	-no problem with -20°C outside temp. experienced -Pineland no problem to -30°C.	-unable to maintain 25°C with outside temp. of -2°C
Heat Distribution	under bench - 16 to 18°C - 2°C warmer along outside wall.	under bench - 13 to 15°C - 2°C cooler along outside wall.
	above bench (ambient air) -1 to 2°C temp. gradient from vacuum to downpipe -no problem along edges.	above bench (ambient air) - no lengthwise gradient, but 1-2°C "cooler" and potential pockets -cooler outside edges.
	above bench (media surface) -no data due to no germination problem	above bench (media surface) -from centre -to side 6°C range with hotspot of 35.4°C in front of burner
Cultural Concerns	required daily spot watering especially during germination i.e. in front of burners not as dry by morning.	required daily spot watering especially during germination i.e. in front of burners were very dry by morning.
	drip patterns below purlins	less drip patterns below purlins.

Table 2: **RELATIVE ADVANTAGES/DISADVANTAGES OF CO-RAY VAC AND AMBI-RAD HEATING SYSTEMS - 1990 Clearwater Nursery TRIAL**
Cont.

FACTOR	CO-RAY VAC	AMBI-RAD
Cultural Concerns	corners take longer to dry out.	corners take longer to dry out.
Crops	small pockets of delayed germination in front of burner - i.e. delayed 3-4 days. 10% @ 5 days. no problem along edges with delayed germination.	large pockets of delayed germination in front of burner - i.e. delayed 7-10 days. 10% @ 9 days. strip of delayed germination along outside edges - i.e. 7-10 days -more crop variability.

Table 3: **RELATIVE ACCEPTABILITY/UNACCEPTABILITY OF CO-RAY VAC AND AMBI-RAD HEATING SYSTEMS BASED ON Clearwater Nursery'S 1990 TRIAL**

FACTOR/CONCERN	CO-RAY VAC			AMBI-RAD		
	ACCEPTABLE	UNACCEPTABLE	N/A	ACCEPTABLE	UNACCEPTABLE	N/A
MECHANICAL						
-Ignition		X (but modified)				
-Indicator Lights			X	X (But Confused Staff)		
-Heat Shields	X				X	
-Available Temp. Sensor		X			X	
-Supplier Support	X				X	
CROPS						
-Germination Time	X				X	
-Germination %	X			X		
-Germination Patterns	X				X	
-Maintained Schedule	X			X (But Slow)		
-Met Spec.	X			X (But More Variability		

Table 3: **RELATIVE ACCEPTABILITY/UNACCEPTABILITY OF CO-RAY VAC AND AMBI-RAD HEATING SYSTEMS BASED ON Clearwater Nursery'S 1990 TRIAL**
Cont.

FACTOR/CONCERN	CO-RAY VAC			AMBI-RAD		
	ACCEPTABLE	UNACCEPTABLE	N/A	ACCEPTABLE	UNACCEPTABLE	N/A
MAINTENANCE						
-Training Required	X				X	
-Ease of	X					X Unknown
-Changing Jets	X				X	
HEATING						
-Maintained Min.	X				X	
-Under Bench Temp	X				X	
-Under Bench Distribution	X				X	
-Under Bench Latent Heat	X				X	
-Above Bench (Ambient Air) Lengthwise Gradient	X				X	
-Above Bench (Media Surface)		X No Data			X	
-Above Bench	X				X	
Lateral (Ambient Air Gradient)	X				X	
SUPPLIER						
-Met Design	X				X	
-Specifications						
-Support	X				X	
-Warranty	5 years			10 years		
-Cost	$11.3			$9.2		
OPERATING COST						
-% Saving vs Conventional	X (31.3)*			X (35.1)*		

+N/A=Not Applicable
*Excludes any potential savings related to labour.

Table 4: **ESTIMATED RELATIVE OPERATING COSTS OF H.P.S. AND INFRA-RED versus CONVENTIONAL LIGHTING HEATING SYSTEMS. (FOR ONE GREENHOUSE FROM FEBRUARY 20 TO JUNE 20, 1990)**

HEAT SOURCE	CONVENTIONAL	CO-RAY VAC	AMBI-RAD
Wood	1135		
Electric	3181	1145	1145
Propane	1854	3095	2860
TOTAL	6170	4240	4004
% SAVING I.R: vs. CONVENTIONAL		31.3+	35.1+

+Excludes potential savings on peak demand and labour.
NOTE: Co-Ray Vac cost approximately 8.2% more for fuel over the trial period - possibly due to longer burn time resulting from intermittent ignition problem.

CONCLUSION:

Given projected increases in seedling demand and the likelihood of no increase in operating budgets, increased operating efficiency is a critical objective for Clearwater Nursery. Based on the results of this six-month trial, infra-red has no significant drawbacks relative to crop quality.

Despite its lower capital cost, 8.2% lower operating cost and longer warranty, the Ambi-Rad system is not preferred due to:

a) Extreme media surface temperatures in front of burners which caused excessive drying and delayed germination.

b) Inadequate heating capacity for moderately cold outside conditions.

c) Reduced thermal mass under benches in the event of a catastrophic failure.

d) Difficulties associated with installation, start-up and modifying burner output.

Clearwater Nursery is starting the conversion process immediately and will have 6 to 8 greenhouses converted to Co-Ray Vac Heating by January 1991. The remaining greenhouses will be converted as funds become available.

CONTAINER PRODUCTION OF SIBERIAN LARCH SEEDLINGS

W.R. Schroeder [1] and D.S. Walker [2]

INTRODUCTION

Siberian larch (Larix sibirica Ledeb.) is a promising shelterbelt species for the Canadian prairies. It was originally introduced from the Soviet Union as a woodlot tree. Its long, straight trunk which can reach up to a diameter of 25 cm, is excellent for rails, poles and posts.

In recent years Siberian larch has been evaluated for planting in field and farmstead shelterbelts. The narrow pyramidal form, fast growth and relatively noncompetitive root system make the tree well suited for this purpose. In addition, the deciduous habit of larch results in a porous tree during the winter which allows for even snow distribution. In spring it is one of the first trees to leaf out, thus maximizing its shelter effect during the critical spring erosion period. Tree heights up to 20 metres are possible on good sites in the prairies.

Siberian larch begins to bear cones at 10 to 15 years of age. Seed crops are irregular with small annual crops and large crops occasionally. Seed production is handicapped by early spring frosts and insects. Seeds per kilogram range from 60,000 to 140,000 with a mean of 80,000. Several seed sources are planted in the prairies including those from the Shelterbelt Centre and the Raivola source used by Alberta Forest Service. Siberian larch has been grown in the prairies since 1906, but only during the last 10 years has a significant number of seedlings been produced by the Shelterbelt Centre.

The following is an outline of the techniques used at the PFRA Shelterbelt Centre to grow containerized Siberian larch for planting in prairie shelterbelts. The schedule has been developed from eight years of research in container production at the Shelterbelt Centre.

PRODUCTION FACILITIES

Seedlings are grown in two facilities, a growth cellar and a greenhouse. The growth cellar is a converted cold storage room heated by one natural gas heater. Lighting is provided by 400 watt high pressure sodium lamps providing a light intensity of 6000 lux. The greenhouse is a glass house heated by hot water circulated underneath the growing benches. Cooling, if required, is provided by evaporative coolers and a 24 inch exhaust fan. The greenhouse is illuminated with 400 watt high pressure sodium lamps at an intensity of 8000 lux. Irrigation water (pH 7.0) is applied with a hose.

SEED INVESTIGATION

Prior to sowing, seed lots are evaluated for viability and germination. Seed viability is determined by the cutting test. If more than five percent of the 100 to 200 seed samples are empty, the seed lot should be reprocessed by blowing to eliminate the empty seeds (1983 Annual Report, p.14). Seed germination is tested in germination trays. Non-stratified seed (four 100 seed replicates) is placed in the trays and cumulative counts are made at 7, 14, 21 and 28 days. At 28 days, any non-germinated seed is cut to determine if they are hollow or round. To determine sowing rate deposit one seed for each 10 percent of germination capacity less than 100 percent.

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[1] Assistant Head of Investigation Section and [2] Propagation and Tree Improvement Technician, PFRA Shelterbelt Centre, Indian Head, Saskatchewan.

CONTAINER TYPE AND MEDIUM

Siberian larch is grown in 350 ml 'Tinus' Spencer Lemaire containers which have 40 cells per tray, or 320 cells per square metre. Before sowing, previously used trays are washed and dipped in a 10 percent bleach solution. Cells are filled with premixed 50/50 peat-vermiculite medium (1985 Annual Report, p.30). The pH of this medium ranges from 4.0 to 5.0.

The medium is lightly tamped into the cells and irrigated thoroughly until the entire cell is wet. Prior to sowing, seeds are soaked for 3 days under a water mist (1983 Annual Report, p.14). Seeds are sown by hand and covered with 5 mm of silica sand or vermiculite (1983 Annual Report, p.17).

GERMINATION PERIOD

After sowing, the containers are irrigated lightly so that the zone around the germinating seeds is kept moist. Damping-off is generally not a serious problem when the following practices are used: silica sand seed covering which allows air circulation around the root collar, delaying nitrogen fertilization until germination is complete and keeping relative humidity low. In the growth cellar, benomyl is applied after germination to prevent root rots.

Cells are thinned to one seedling as soon as the majority have shed their seed coats. Extra seedlings are carefully transplanted in empty cells. Thinning and transplanting is easier and more successful if done before lateral root development. Germination is generally complete within 8 to 10 days and seed coats are shed within 14 to 18 days at which time the seedlings enter the 'early growth period'.

EARLY GROWTH PERIOD

The objective of this growth period is to develop root systems on the germinants and height growth. Nutrients are applied during each twice-weekly irrigation (1985 Annual Report, p.29). Initially (week 2 through 5) a fertilizer solution of Plant Products Seedling Starter (11-41-8) at a rate of 100 ppm N (151 g/L water)is applied.

From weeks 5 through 15, Plant Product Seedling Grower (20-8-20) at a rate of 250 ppm N (210 g/L water) is applied. During this growth period, day temperatures of 24 to 27°C and night temperatures around 18 to 20°C are maintained (1983 Annual Report, p.16). Photoperiod is extended to 18 hours using high pressure sodium lamps to supplement natural daylight.

At the end of week 16, the medium is leached with water to remove any salt buildup. Weekly height and root collar diameter measurements are taken on 10 predetermined sample trees. This data is compared to a target growth curve. If height growth is occurring faster than the target, rates of applied nitrogen are reduced. Conversely, if growth is slower, nitrogen rates are increased.

BUD INITIATION PERIOD

The objective of this growth period is to reduce nutrients and moisture, creating a stressed condition in the seedling so that height growth will cease, terminal buds will develop and root collar diameter will increase. In week 17, seedlings are moved from the greenhouse to the outdoor shadehouse. Seedlings are now only irrigated when the medium has become barely moist. Seedlings are selected at random every second day, the root plug is removed from the cell and then visually examined for degree of dryness. Generally, seedlings will require irrigation once per week. Fertilization using Plant Products Seedling Finisher (8-20-20) at a rate of 100 ppm (210 g/L) is applied once per week. Seedlings will continue to grow for 4 to 6 weeks. After 8 to 10 weeks of reducing nutrients and irrigating sparingly, the larch begin to set terminal buds.

Bud initiation and dormancy induction is slightly different for seedlings grown in the growth cellar (1983 Annual Report, p. 18-19). After 16 weeks seedlings are drought stressed for two weeks, photoperiod is reduced to 8 hours and fertilization discontinued. During the final four weeks, temperature is reduced to 10°C. After 10 weeks the seedlings should have defoliated, set bud and are ready for outplanting.

COLD ACCLIMATION PERIOD

Beginning in late September, trees will begin to defoliate. Seedlings are watered every 2 to 3 weeks during this period and no fertilizer is applied. It is during this stage the trees acclimate and attain maximum cold hardiness. By mid to late October, seedlings have defoliated, are fully dormant and ready for freezer storage.

EXTRACTION AND COLD STORAGE

Seedlings are well watered before being removed from their containers and tied in bundles of 10. Bundles of trees are placed five to a bale (50 seedlings total) and then placed in freezer storage. The storage room is kept at -2°C. Seedlings stored under these conditions withstand seven months of storage with no loss in quality (1985 Annual Report, p.16). Refrigerated storage at 1°C is not recommended because bud break can occur near the end of the storage period.

CONCLUSION

This growing schedule has been very successful especially under greenhouse conditions. Seedlings grown under this regime average 30 cm in height and 3.0 mm in caliper. First year outplanting survival under good growing conditions has averaged 87 percent over the past seven years. The most important aspect of the schedule is monitoring the seedlings as the schedule progresses. Height and caliper measurements are used to modify the schedule according to seedling growth.

GROWING SCHEDULE FOR SIBERIAN LARCH

Month	February		March					April				May				June				July				August				September				October				November			
Week	-1	01	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Growth stage	Sow	Germ	Initial growth				Height growth												Caliper and height growth in shadehouse											Hardening in shadehouse						Storage -2°C			
Temperature		25°C (day) 18°C (night)																	Ambient Temperature											Ambient Temperature									
Light		6000 Lux	6000 Lux 18 hour photoperiod																Natural day length											Natural day length									
Irrigation	mist during heat of day		Twice per week with nutrient solution. Medium near field capacity														Leach		Irrigate when root plug is barely moist											Irrigate every 7 to 10 days						Irrigate just prior to storage			
Fertilization			starter applied twice per week				Seedling grower applied twice per week												Seedling finisher applied at each irrigation								No fertilizer												

RGC TESTING AT PINELAND NURSERY

Wendy Kozmak
Bareroot Supervisor

Root growth capacity (RGC) testing has been used for the last two years at Pineland Nursery to help assess the quality of stock in storage. RGC's are done on stock in frozen storage as well as spring lifted stock to help management and field personnel to determine the quality of stock and predict potential problems in stock survival after planting.

The sampling procedure we have been using is as follows: Starting in February, representative stock lots are selected from bareroot and container crops in frozen storage. Samples are collected from these stock lots monthly till May and then bi-weekly till shipping is completed. Frozen bundles are thawed at +3°C before potting. Fresh stock from the spring lift is sampled and potted the day of lifting and then bi-weekly until shipping is completed. Stock destined for snow caches is sampled and potted when it leaves the nursery, if possible, samples are sent back to the nursery for potting when the snow cache is opened.

The procedure for the potting test is based on the system used in British Columbia, with some modifications to suit the species and stock types we are testing. Sixteen seedlings are potted in 2-1-1 peat-vermiculite-perlite mix in 15cm pots. Bareroot stock is potted 2 per pot, and container stock 4 per pot so tests don't take up too much bench space. The pots are thoroughly watered and placed in one of our operational greenhouses, where they receive 18 hours of light, and temperatures of 25°C during the day and 22°C at night. Because the tests are in operational houses however, the temperatures cannot be fixed for the test conditions, and tests have to be moved from one house to another through the growing season. Pots are allowed to dry back between waterings and after 21 days, the amount of root activity is measured using the scale described in Figure 1.

In addition to the amount of root activity, other observations recorded are the degree of needle loss, needle appearance, buds swelling and length of flush. At the end of the growing season, the survival from outplanting trials are plotted on the RGC graphs.

The results are used in two ways: short term decisions and long term planning. In the short term, if a stock lot showed up poorly in an RGC test a serious look would be taken at remaining stock to determine if planting should continue. In the long term, the data can be used to help evaluate lifting and storage conditions, scheduling of stock types for spring/fall lifting and planting order in the spring. There are, however, some limitations with this testing procedure, the two main areas being: 1) the length of time it takes to get results; 21 day tests are too long to meet short term needs, and 2) the fact that low RGC values can not always be equated to low survival. Seedlings with low RGC can have high survivals in optimum planting conditions.

In summary, RGC results can be a valuable tool in evaluating seedling quality and potential performance. However, planting conditions, time frame in which seedlings can be planted, and prior RGC records for various stock types must also be taken into account to make sound decisions.

Figure 1

INDEX OF ROOT GROWTH
(BURDETT 1977)

0 = No new (white roots)

1 = Some new roots, all less than 10 mm in length

2 = 1 to 3 new roots longer than 10 mm

3 = 4 to 10 new roots longer than 10 mm

4 = 11 to 30 new roots longer than 10 mm

5 = 31 to 100 new roots longer than 10 mm

6 = 101 to 300 new roots longer than 10 mm

STOCK PERFORMANCE IN FIELD CONDITIONS
WHERE DO WE GO FROM HERE

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The inclusion of field foresters at the Annual Nursery Association Meeting is just another example of the interaction that is taking place in Manitoba between the nursery staff and the field silviculturalists.

Before it is possible to address the question of "Where do we go from here?", it is necessary to look at "Where did we come from" and "Where are we now".

WHERE DID WE COME FROM

When Abitibi-Price, Pine Falls, signed its Forest Management Licence in 1979 we had no silvicultural experience in the Prairies. The Province of Manitoba also had limited reforestation efforts on our licensed area. Abitibi hired Ken Armson as a consultant to assess the opportunities and provide recommendations.

The facilities at Pineland Nursery were inadequate to grow the range of stock required. The nursery also lacked the technical expertise necessary to produce consistently good crops.

One of Mr. Armson's recommendations was the production of Japanese paperpot container stock. Unfortunately it took us five years to realize that the paperpot system would not work in Manitoba's clay soils. The tendency of the clay to be cold and wet in the spring and hot and dry in the summer almost seems to have strengthened the paper. The clay would not allow a root system to develop from the bottom of the pot so the only seedlings to survive were the ones that were planted an inch or two deep. This allowed a new root system to develop from the stem; however, it took 5 or 6 years in some cases. There are some ten year old plantations that are still two to three feet tall. There are some exceptions where the paperpots are doing well but the majority of them were planted on recent burn sites.

Another problem arose from the planting window related to the past 2 crop system. Seedlings were not available for outplanting until mid-June. This coupled with the droughts of the 80's left us planting through the hottest, driest periods of the summer. Spring lifted bareroot stock also posed some problems because the nursery would sometimes be lifting three weeks before we were able to start planting. When this was coupled with closures due to forest fires, the planting program sometimes only began as the viability of the cold stored stock began to fall off.

The outdoor overwintering of paperpot crops was also a risky business. Low snow levels and the prairie warming trends in March combined to desiccate entire crops some years.

WHERE ARE WE NOW

The Canada/Manitoba Forest Renewal Agreement was instrumental in assisting Manitoba to upgrade Pineland Nursery to its present status. This enabled the Province to attract the technical expertise it required to run the facility.

Interaction between field personnel and nursery staff enabled the production of the current crop now available for outplanting. The current crop is ready for planting in mid-June. When it comes to the field, the bud has been set and it is shut down for the year. This enables the seedling to concentrate on root production, increased calliper and bud development. The fact that the seedling does not have to worry about an actively growing top while trying to become established, has greatly assisted in the successful establishment of plantations through the drought periods. In the growing seasons following establishment, the current crop seedlings have consistently provided survival figures in the high 80's and low 90's with average current annual growth increments of six to eight inches in the first few years.

The cold storage/freezer facilities at Pineland provided much greater flexibility to the planting program. The nursery staff are able to manipulate the planting window to some degree. In cases where a forest fire delayed the planting projects for two to three weeks, the stock that had not been thawed could be held over with little or no damage. With the change to rigid growing containers and overwinter frozen stock, the winter desiccation problems have been eliminated and the establishment and growth of the plantations greatly increased.

There are still inconsistent results with bareroot stock. We have had serious problems of entire spring lift plantations browning off after planting. Some areas that were considered complete write-offs were replanted the next year. For some unknown reason a good percentage of the seedlings came back to life the next year. They are now vigorously growing resulting in overstocking. The initial indications of the overwinter frozen bareroot stock is that this problem may be solved.

WHERE DO WE GO FROM HERE

We feel that the present system, with the variety of stock types available, provides the flexibility necessary for a successful forest renewal program. Through future experience and fine tuning of the system, even greater gains should be evident.

Manitoba requires a unified stock transportation system for the forest industry and the provincial forest regions. Discussions have been taking place for the last few years. A new Federal/Provincial agreement would be very beneficial in developing the proper system.

The freezer facility is another area that will continue to show gains in outplanted seedlings. As the nursery staff works with the facility they will gain more experience on its capabilities. Documentation of plantations and outplanting trials will enable the staff to establish more definite parameters on storage periods.

One question I would like to pose to you, the professionals, is can bareroot performance ever be as good as containers? With the advances that have been made in container production over the last ten years and considering all the stresses bareroot seedlings are subjected to, I just wonder if container capabilities have not surpassed that of bareroot.

Abitibi Pine Falls is currently undergoing an Environmental Impact Assessment of its 8 year operating and renewal plan. One point that is coming across through the public participation process is the necessity for a road retirement program. We will be looking at planting many kilometres of road in the near future. In assessing stock performance on cutover versus recent burnt sites, the burn sites consistently outperform the cutover sites. We attribute this to the increased availability of nitrogen on the burn sites. We are interested in knowing the status of time release fertilizers for planting these nutrient deficient sites.

One thing the nurserymen can look forward to in the future is improved seed to work with. We have collected cones from superior stands and kept them separate from general collection cones. The Pineland Nursery staff indicated that the production of a crop was easier using the superior seed because of the tendency of the entire crop to respond at the same time. This held true from germination right through to hardening off. The tree improvement programs that have been established in the last few years will make the collection of superior seed even easier in the future.

The last area where we expect to see improvement is with the inclusion of Repap Manitoba in the provincial picture. This will provide us with one more pair of eyes on the silviculture scene. The interaction of all groups involved cannot help but to improve our reforestation programs.

Heat Tolerance of Tree Seedlings and its Importance to Nursery Managers

Steve Colombo - Ontario Forest Resource Institute

Environmental stresses such as freezing and heat are important factors which affect the nursery production of tree seedlings. While frost hardiness of tree seedlings has deservedly received a great amount of attention, in comparison, heat tolerance has not been as great a concern to nursery managers. Nevertheless, heat tolerance and heat damage are important factors which affect container seedling production in Canada. Like freezing, heat is a stress experienced by trees, and both heat and frost are responsible for damage and mortality in container nurseries.

This paper describes some factors which influence the heat tolerance of tree seedlings, and what importance this has in container nursery management.

1. Symptoms of Heat Damage

High temperatures cause damage to tree seedlings in three main ways. First, by inhibiting germination, second, by heat-girdling of stems near soil level, and thirdly, by damage to the needles and buds.

a. Germination

Unexpectedly low rates of germination are often the only clue that there has been a high temperature problem. In some cases, close examination may reveal germinants in which the root has failed to grow down into the soil. This failure of the first root to emerge from the seed to grow down, called a loss of geotropism, is a characteristic of high temperature damage to germinants. In such a case the root will grow along the soil surface, and eventually, the root and seed dry out and die.

Ideal temperatures for germination in species such as jack pine, white pine, red pine, and black spruce are between about 15 and 25°C, as was published close to 20 years ago (Fraser 1970a,b, Kamra and Simak 1968). However, it has been my observation that most greenhouse managers have as their objective maintaining a temperature of close to 30°c during germination, even thought this is well above the optimum.

Figure 1 shows the results of a trial I conducted to look at the germination of black spruce seed on a peat growing medium at constant air temperatures of 15, 20, 25 and 30°c. While germination was initially faster with temperatures of 25 and 30°c, final germination was best with an air temperature of 15°C. The very poor germination at 30°C is clearly evident.

The risk of poor germination at high temperatures is not well brought out in the standard greenhouse growers references. For instance, Tinus and McDonald in their 1979 USDA handbook, state: *'during .. germination..Seeds (should be) kept moist and reasonably warm (18 to 21°C). Higher temperatures may result in germination of conifer seed, but may result in excessive hypocotyl development.'* Carlson, in his 1983 guidelines for growing conifers in the prairie provinces, states: *'..The warmer part of the temperature range will bring about more rapid germination..'*. This may have led some nursery managers to believe that for best germination, you should use hot temperatures. This is a dangerous misunderstanding.

To avoid high temperature damage during germination soil surface temperatures should be kept at about 20°C c, and should not exceed 25°C. However, container surface temperatures can be high, even if air temperatures a few centimetres above the soil are not.

The buildup of high surface temperatures depends on several factors, the most important of which are the colour of the soil surface - dark colours resulting in the greatest heat buildup; the moisture content of the soil surface layer - dry surface material allowing temperatures to rise more quickly; and the wind speed - where still air allows the buildup of high temperatures further above the soil surface. A greenhouse which is not being vented and where there is a dry, dark container surface will be most prone to high surface temperatures.

Probably the easiest thing which can be done to reduce surface temperatures is to apply cool water during the day when high surface temperatures are suspected. Figure 2 shows the effects of cold water on soil surface temperature. Air temperature was 30°C, and water of 0.5, 6 And 20°c was applied. In 30°c air the soil surface temperature was just over 29°. Temperature of the soil surface dropped almost instantaneously to the temperature of the water being applied. Four minutes after watering, soil surface temperature was still greatly depressed. Even after 60 minutes, soil temperature was depressed by up to 5°c.

However, nursery managers may be apprehensive about applying cold water to germinating seeds on a hot day, for fear of causing damage to the germinants. Figure 3 shows the effect of cold temperature water on the germination of jack pine seed when air temperature was 30°C. Four water temperatures were used - ranging from 0.5 to 20°C. Far from cold water having a negative effect on germination, at an air temperature of 30°C, germination was better the colder the irrigation water. Using 20°C water, germination was a maximum of about 44 %, while with 0.5°C water, germination was almost 80%. I attribute this directly to the cooling effect of cold water.

Figure 4 shows the germination of black spruce seed with an air temperature of 15°C and different irrigation water temperatures. There was again no detriment to germination using cold water.

I know many nurseries use heated water out of fear of causing damage to seedlings on hot days. I would suggest that, during germination, especially during hot weather in the spring and summer, that water heaters be turned off. Growers could then apply cold water to keep soil surface temperatures down.

The fact that many greenhouse managers purposely try to maintain temperatures close to 30°C for germination may mean that many of the germination problems put down to low seed quality, are in fact due to high soil surface temperatures, and that this explains many of the discrepancies between seed plant germination values and nursery germination results.

b. Stem damage

Stem damage due to heat in recent germinants may be easily mistaken for damping off. According to Tinus and McDonald (1979), damping off appears as: *'a water soaked or necrotic lesion, which collapses and the seedling falls over'*.

Stem heat damage, in comparison, appears as a constriction of the stem at soil level, and at the point of this constriction the seedling may fall over or break off. The similarity between stem heat damage and damping off means that often the only sure way to differentiate between the two is to keep track of container surface temperatures and to have isolations for damping off fungi done. In addition, stem heat damage will tend to occur in patterns within the greenhouse, as opposed to the more random occurrence of damping off.

Stem heat damage is more of a risk the smaller the stem diameter. As a result, recent germinants will be most susceptible to stem heat damage. As seedlings grow, the shading provided by lateral branches and foliage will help to reduce heat buildup of the soil surface. One factor which can affect stem heat damage is the colour of the mulch used. A dark mulch such as chicken grit will be hotter than a lighter coloured mulch such as vermiculite, styrofoam beads or silica.

c. Needle damage

Heat damage to needles can show up either shortly after high temperature exposure, or will gradually appear over two to three weeks after exposure. Heat damage which shows up shortly after exposure occurs at higher temperatures and with longer durations of exposure than damage which shows up more gradually. As is also the case with seeds and stems, damage to needles increases with temperature and the length of exposure, and there are sharp gradients in exposure levels resulting in damage.

Figure 5 shows temperatures and lengths of exposure causing 50% needle damage in actively growing black spruce container stock. Fifty percent damage was caused by 105 minutes at 44°C, as well as by only 5 seconds at 60°C. Between 44 and 50°C, the time of exposure causing damage dropped very quickly. Above 50°C, damage occurred in a matter of minutes or seconds.

High air temperatures in greenhouses occur as a result of intense sunlight and high air temperatures outside. Even with a favourable ratio between fan capacity and air volume in the greenhouse, on sunny days, greenhouse temperatures will be hotter than air temperatures outside. Growers with greenhouses prone to high temperatures may have insufficient fan and vent capacities for greenhouse size. In such cases, additional fans and/or vents could improve cooling.

Greenhouse air temperatures can be reduced using evaporative cooling, by misting water into the air. However, without proper management, misting can actually cause higher temperatures in seedlings. The amount of cooling from misting depends on the rate of evaporation, which in turn depends on relative humidity. At high humidities the rate of evaporation will be low, while low humidity permits more rapid evaporation, and better cooling. Because humidity can build up to near saturation levels when the greenhouse is not being vented, nursery managers should ensure that misting for evaporative cooling is combined with sufficient air flow.

In addition, water vapour is one of the so-called 'greenhouse' gases, and can trap heat inside in the form of infra-red radiation. A greenhouse with inadequate ventilation could rise to higher temperatures with misting than a well-watered crop without misting. So, for a greenhouse to be cooled using misting, good air exchange is essential.

Another method of evaporative cooling is the use of wetted pads in place of louvres. In this system, air is cooled as it is drawn through the wet pads. Several systems are available commercially.

High greenhouse temperatures can also be avoided by reducing solar radiation using shade paint or shade cloth. The disadvantage of shade paint is that it is not easily removed, and will result in very low light levels during cloudy weather. The same difficulty in the use of shade cloth also occurs unless the shade is easily retractable.

In the same way as air is cooled by evaporation, leaves are cooled by transpiration. However, when trees lose the ability to cool by transpiration needle temperatures rise well above air temperatures. Needles on trees are extremely efficient at capturing light for photosynthesis. This light harvesting ability, however, works against the plant - when transpiration is limited. Then the same solar radiation needed for photosynthesis can cause needle temperatures to rise, and, without the cooling effect of transpiration, temperatures in spruce needles may be as much as 14°C above air temperatures (Smith and Carter 1988). It is important to note that transpiration can be slowed or caused to stop in plants either as a result of a lack of water in the growing medium or due to very high levels of relative humidity in the air. It is likely that seedling mortality in dry containers in greenhouses is due to high temperature damage when transpiration is limited, rather than being directly due to drought.

4. The effect of nursery practices on heat tolerance

Needle heat tolerance depends a great deal on cultural factors under the control of the nursery manager. Among the factors which affect heat tolerance, are the stage of growth of the crop, fertilization, temperature and light regimes.

a. Stage of Growth

Large differences in heat tolerance occur depending on the stage of growth of the crop, whether seedlings are actively growing or dormant (Koppenaal and Colombo 1988). Dormant seedlings are by far the most resistant to heat damage. The least resistant stock is that which is actively growing. Stock in which buds set again after having flushed have greater heat tolerance than actively growing stock.

At the present time only a fraction of overwintered container stock is planted when dormant. In addition, the use of short-day treated spruce container stock, which flushes earlier than natural-day stock, is resulting in a greater amount of stock having broken bud at the time of shipping than only a few years ago. This is a major reason for supporting the use of frozen storage for overwintered container stock.

Using frozen storage it is possible to plant dormant, highly stress resistant seedlings throughout the summer, with no loss in seedling vigour or field performance (Odlum and Colombo 1989). By planting actively growing, overwintered container stock, plantations are being unnecessarily exposed to increased risk of failure due to heat as well as other stresses.

The same benefits of enhanced stress resistance also apply to current crop spruce container stock. For this reason, terminal buds should also be initiated in current crop spruce using short day treatment prior to planting. Facilities for daylength control allowing short day treatment are now present in many container nurseries.

b. Heat Tolerance and Nursery Fertilization, Light Intensity and Temperature

Heat tolerance can also be affected by nursery practices such as fertilization, light intensity and temperature. In several trials I have conducted it has been observed that a two to three-week-long conditioning period has a major effect on the heat tolerance of black spruce and jack pine container stock.

In one such trial actively growing first-year black spruce and jack pine container seedlings were exposed to a factorial combination of two levels of temperature (15°/10°C versus 30°/20°C day/night), high and low light levels (equivalent approximately to full and half sunlight), and a 20-20-20 Plant Products fertilizer at levels of 0, 75 or 300 ppm nitrogen applied twice weekly. Treatments lasted for three weeks, after which the heat tolerance of the shoots was tested by exposure to 47°C for 30 minutes.

For black spruce, there were wide differences in heat tolerance due to light and temperature. High temperatures and lower light intensities produced seedlings which were the most heat tolerant. Seedlings kept at lower temperatures were more damaged by heat. There were no significant differences in black spruce due to fertilizer treatment, although in other trials higher fertilization rates have been found to significantly reduce heat tolerance.

For jack pine, lower temperatures again resulted in greater susceptibility to heat damage regardless of fertilizer treatment. At warmer temperatures, differences in heat tolerance were related to fertilizer rates, where seedlings which were fertilized most heavily, were most damaged by heat exposure. At high light levels and warm temperatures, fertilization at rates of 75 or 300 ppm nitrogen resulted in lower heat tolerance. At lower light levels and warm temperatures, seedlings fertilized at the 75 ppm rate were more heat tolerant.

c. Heat Shock Conditioning

It has been known since the mid-1950's that heat tolerance in plants is increased by exposure to a high, non-damaging temperature. Although the heat shock has been shown for most agricultural species, it has until very recently not been documented in forest tree species. It has been found at OFRI that black spruce, white spruce and jack pine seedlings are all capable of responding to heat shock.

Figure 6 demonstrates the drastic difference in heat tolerance between heat shock and non-heat shock black spruce. Seedlings were heat shock conditioned by exposing them to a temperature of 38°C for three hours per day for six successive days. At the end of this conditioning period heat tolerance of heat shock and non-heat shock trees was tested by exposing them to 47°C for increasing durations of time. Heat damage was assessed three weeks after exposure to 47°C.

Heat shock can be seen to increase heat tolerance significantly. For instance, 60 minutes at 47°C resulted in almost total kill of normal, non-heat shock seedlings. Sixty minutes at 47°C caused almost no damage to heat shock seedlings. Other work has shown that this heat shock treatment lasts several weeks after the end of the last heat shock exposure.

Heat shock is a commercially feasible practice. In the optimum treatment, the temperature in a well-watered greenhouse is raised to 38°C, for 3 hours per day, over 6 days. This can be done using solar heating and proper ventilation control, although this would require strict attention throughout temperature exposure to ensure that a lethal temperature was not reached, and that there were no dry containers which would prevent evaporative cooling by transpiration. A safer but much more costly means of applying heat shock would be to raise the temperature using greenhouse heaters at night.

Conclusions

In closing, looking at the various factors affecting heat tolerance, certain things can be done by nursery managers to make a difference in the heat tolerance of planting stock. For instance:

Greenhouse temperatures can be kept between 15 and 25°C during germination of most boreal coniferous species. In addition, container growing medium surface temperatures can be cooled using irrigation water on hot days. A light-coloured mulch will help to moderate container surface temperatures.

By using frozen storage of container stock, it can be assured that most stock will be dormant when planted. Some container nurserys can increase heat tolerance by initiating container nurserys can increase heat tolerance by initiating budset in current crop stock.

The decision might be made to cut back on rates of fertilizer within 3 weeks of shipping, to increase heat tolerance in jack pine.

Heat tolerance can be increased by treating seedlings with heat shock by at temperatures of 38°C for three hours per day for six days.

The problems of nursery stock production and forest regeneration need to be approached in new ways, and using new technologies. The sooner physiological mechanisms such as heat tolerance are understood, and improved practices based on this understanding developed, the more successful will our regeneration efforts be.

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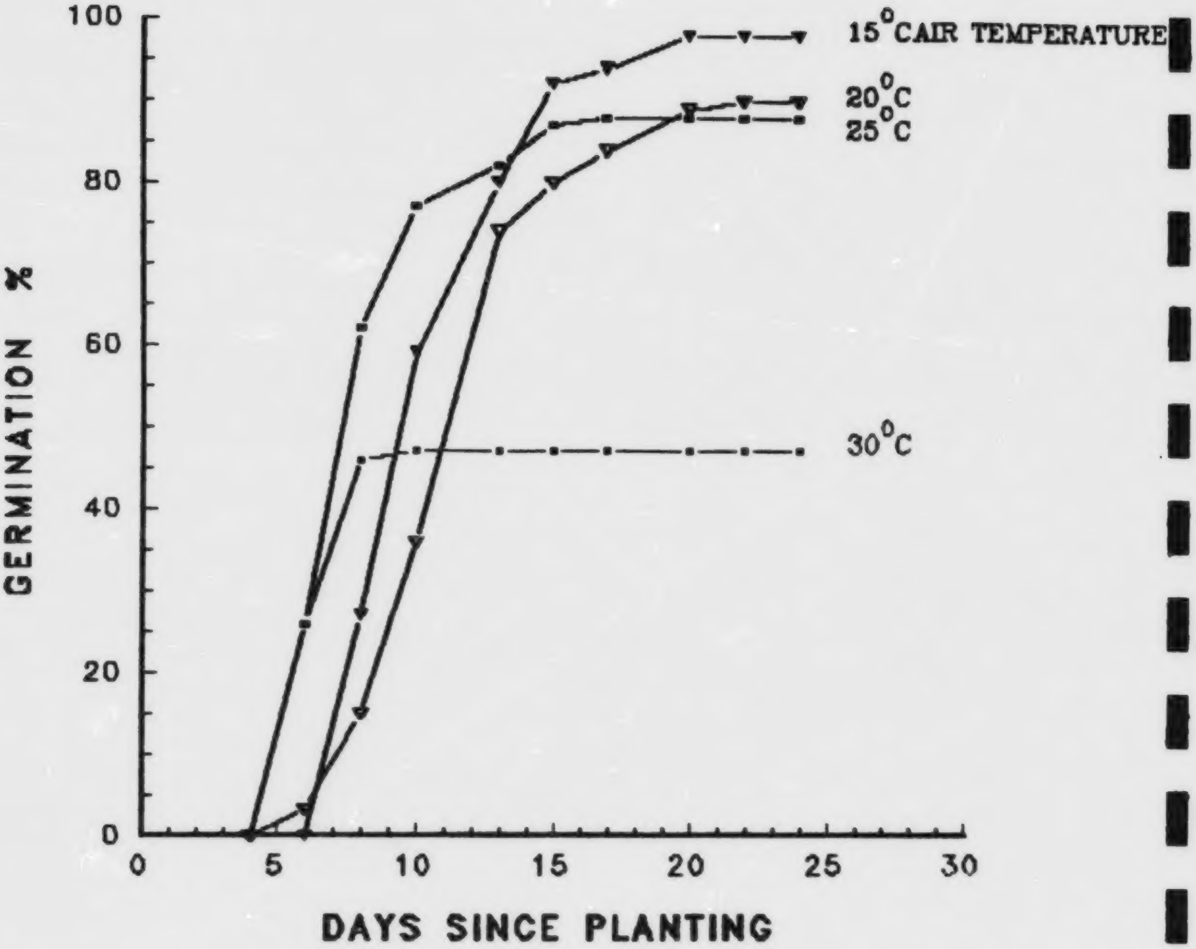

Figure 1. Germination of black spruce seeds at different air temperatures.

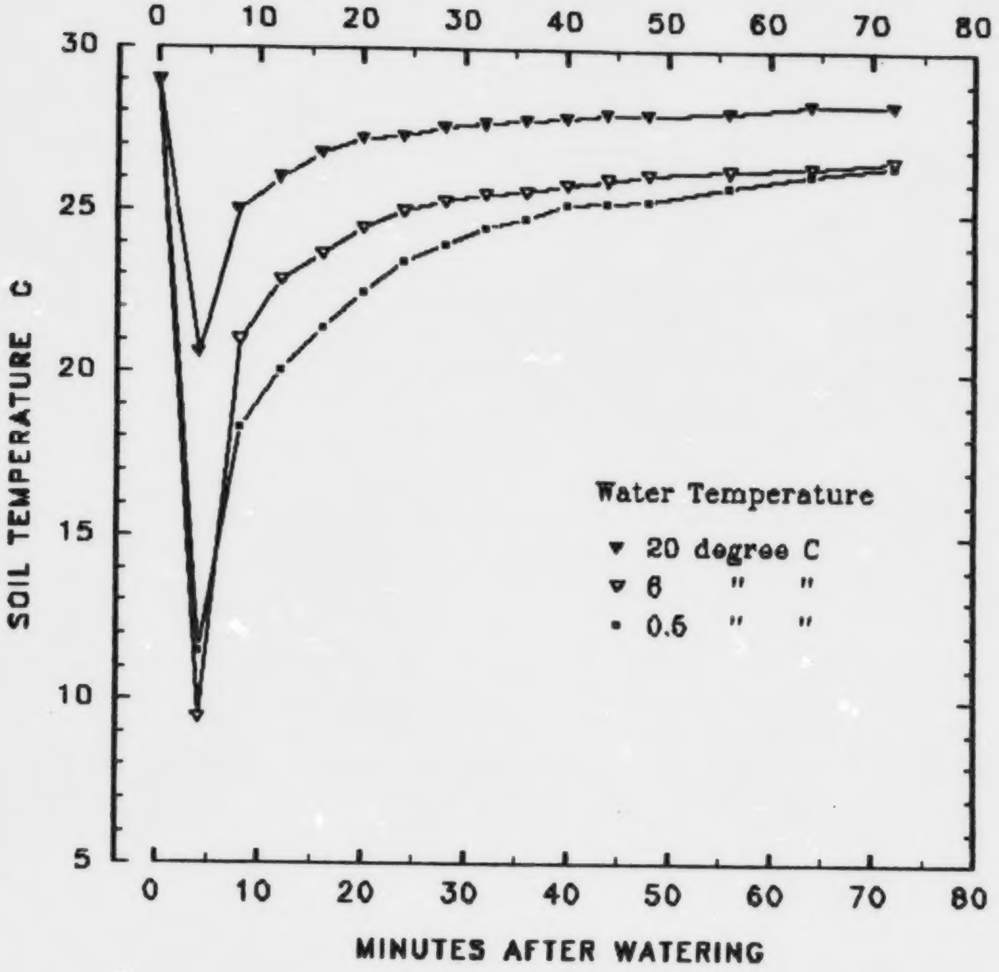

Figure 2. Soil surface temperature of a peat growing medium watered with different temperature water at 30°C air temperature.

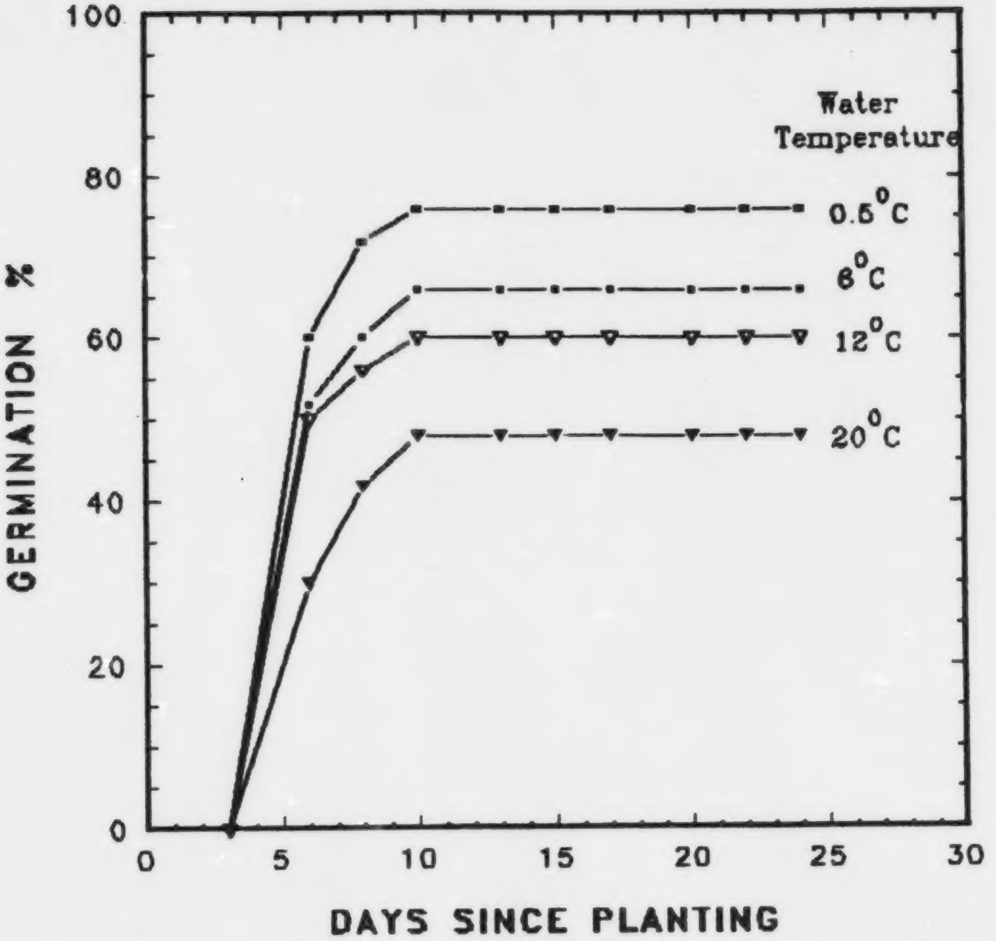

Figure 3. Germination of jack pine seeds using different temperature water at 30°C air temperature.

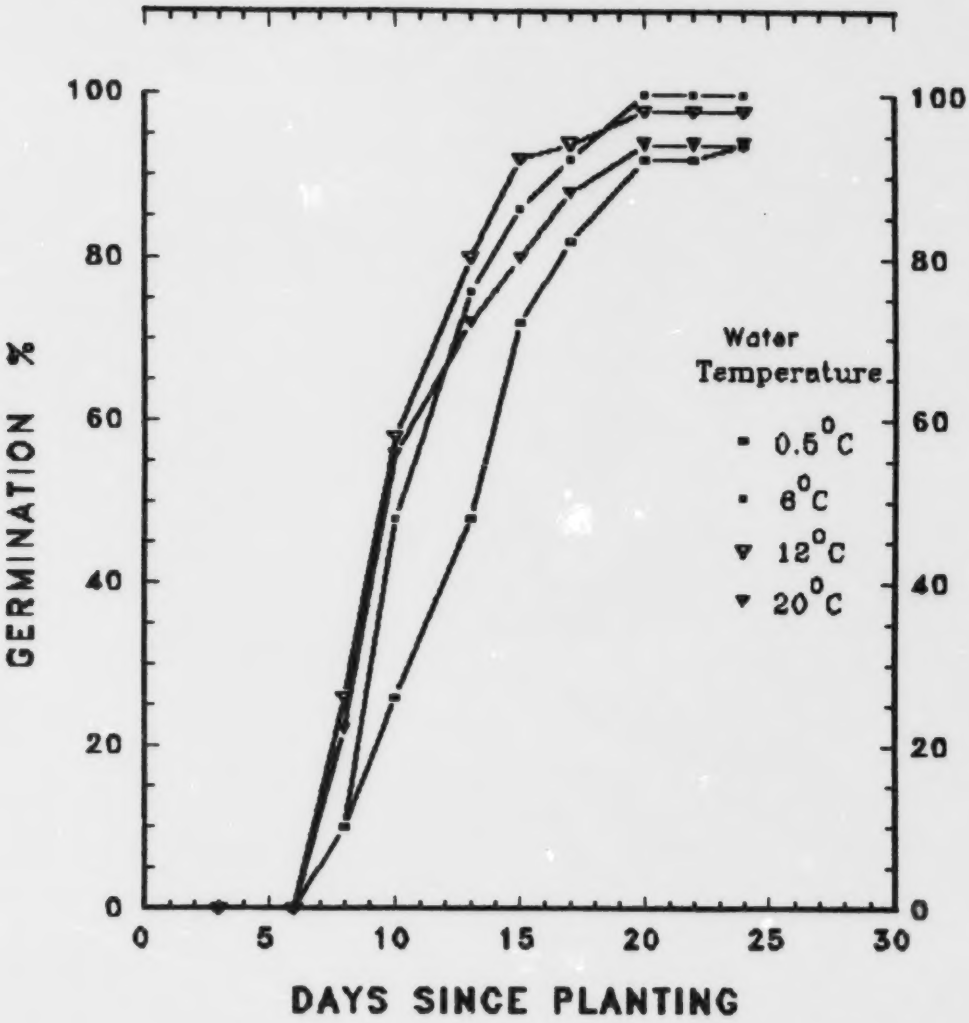

Figure 4. Germination of black spruce seeds using different temperature water at 15°C air temperature.

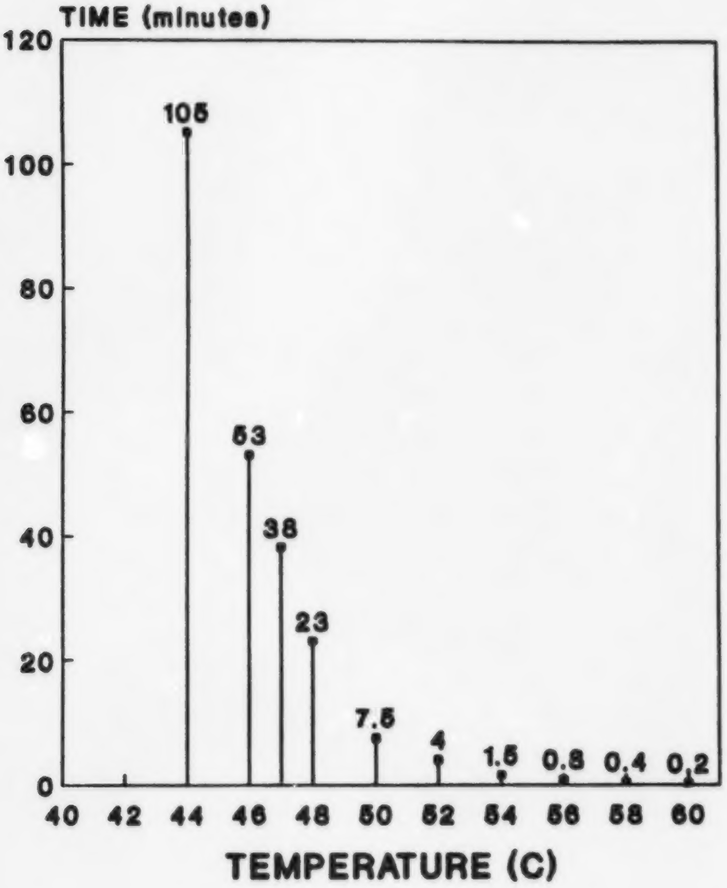

Figure 5. High temperature exposures causing 50% needle damage to actively growing first-year black spruce seedlings.

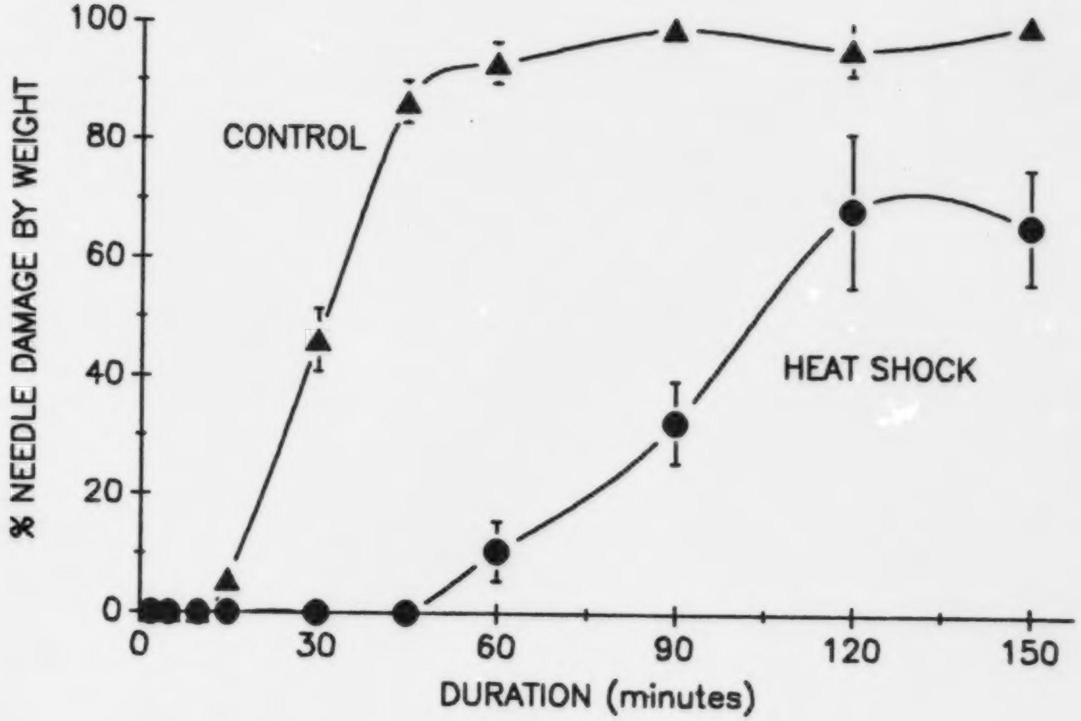

Figure 6. Needle damage to heat shock conditioned and typical 'control' actively growing black spruce seedlings exposed to 47°C for increasing lengths of time.

PROPOSED OPTION FOR REARING QUALITY CONTAINER SEEDLINGS

Sept. 1990

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PROPOSED OPTION FOR REARING QUALITY CONTAINER SEEDLINGS

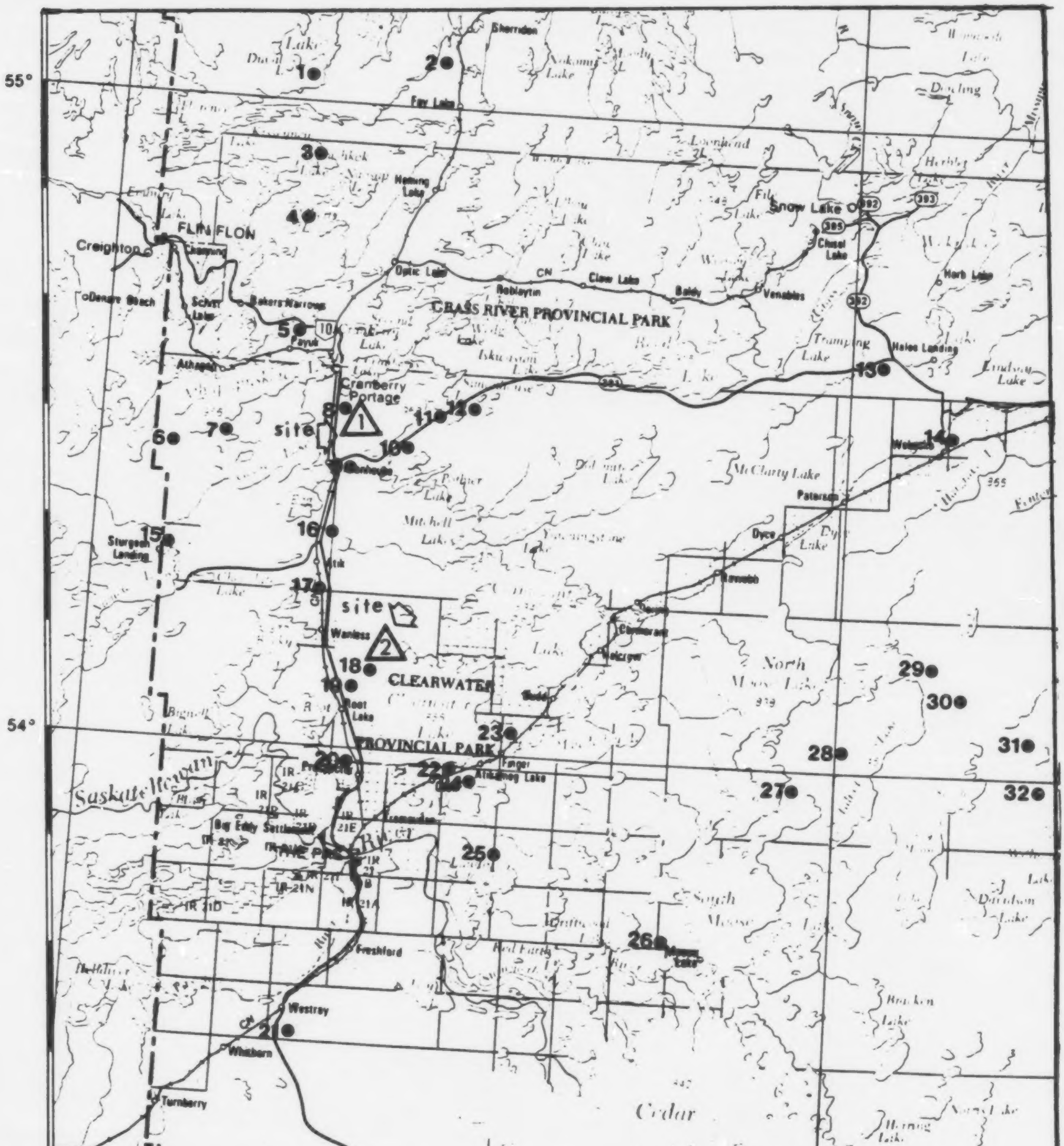
Today I will address stock growing options that provide incentives to the entire forest renewal management system. As we stride into the closing decade of this century, many industries around the world have demonstrated the benefits of working together towards a common goal. This is equally true in the forest renewal business. Nursery, silviculture, forest management, industry and the general public must work together to towards a healthier life for trees and people.

I will present one case-example from the tree improvement program that worked towards a common goal. The goal was to produce quality seedlings that would have high survival and rapid growth rate for several years after planting.

This was achieved by ensuring that the tree improvement program focused towards a common goal. The program focused all important aspects like planting, site clearing and preparation, greenhouse environment for stock rearing, selection of container type and size, stock rearing option, stock conditioning, and planting supervision. I believe similar goals can be achieved to meet common goals of operational scale forest renewal business.

In the case-example, I will outline clearing and preparation of planting site, greenhouse environment, container selection-type and size, stock rearing procedure,stock conditioning planting schedule and four-year field performance. Next, I will explain how the proposed stock growing option could work for you, by discussing just some of the most important factors such as costs and benefits.

In order to identify superior jack pine seedlings from 320 selected parent trees, we (needed to) reared and fielded test 40,000 seedlings. In order to get meaningful results these seedlings would have a high survival and good rate of growth on highly competitive sites for several years after planting. **(Figure 1.** Illustrates distribution of seed source and test site locations in northern Manitoba.) The test area was cleared with a dozer blade by knocking down all trees and debris removal with a brush-rake without removing organic material during March of 1986. All organic (forest duff) material remained virtually undisturbed with this method. It was imperative that site degradation not take place during establishment phase. The planting site was intensively prepared with an off-set disk implement by making several passes in May of 1986,two months prior to planting. To prevent site degradation and burial of organic material while discing,the disk implement was set to a maximum depth set of 15cm.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Cranberry Portage
Snow Lake
GRASS RIVER PROVINCIAL PARK
CLEARWATER
PROVINCIAL PARK
Sturgeon Landing
North Moose Lake
South Moose Lake
Cedar
Saskatchewan
Freshford
Westray
Whitbern
Turnberry
Paterson
Dyce
Wanless
Atikameg Lake
Herb Lake
Wekusko
Tramping Lake
Mitchell Lake
McClarty Lake
Sherridon
Optic Lake
Athapap
Bakers Narrows
Cormorant
Root Lake
TCHEWAN
10
392
393
395

Figure 1. Distribution of test stands (seed sources) and test sites.

The removal of organic material and deep churning of Boreal soils during site preparation causes serious site degradation. (There should be a law to prohibit such methods that cause removal of organic material on forest lands.) There is nothing more detrimental than clearing planting sites during summer or when the ground is not frozen. The uprooting process brings heavy clay to the surface and dilutes organic and soil fertility.

To meet program goals, a multi-purpose tree improvement greenhouse was built to provide the necessary environment to grow quality stock. One key spin-off (technology transfer) from the tree improvement greenhouse is the demonstration of how high pressure sodium (HPS) light can benefit in the production of high quality seedlings. I will now refer you to **Table 1.** for a comparison of four different container nursery (greenhouse) environments. Greenhouse environment types ■ A ,and ■ B are commonly used to grow seedlings for forest renewal. Greenhouse environment type ■ C was used to grow seedlings for the tree improvement field performance test which I will use to illustrate 4-year field performance. I will refer to greenhouse environment type ■ D later, during my key discussion on proposed rearing option.

In view of the fact that container reared jack pine seedlings are prone to root deformation when planted in heavy clay soils, precaution was taken to reduce such risks. Spencer-Lemaire/Hillson, 175 ml containers were selected as best option because of (a) ease of seedling arrangement opportunities (b) container modification opportunities to enhance additional root-tip development and (c) reduction in root deformity risks at targeted seedling specification. Container modification was easily accomplished by cutting a 3mm x 35mm slit across the container with a radial arm saw approx. 25mm above the base.

Field performance test stock was reared in greenhouse environment type ■ C according to culture period shown in **Table 1.** After a 11 week growth phase and a 9 week hardening phase (conditioning) the stock met targeted specification (stem diameter 4mm and stem height 200mm) at 20 weeks (June 30), see **Figure 2.** for average height and diameter at planting time. Since the stock met all specifications and was physiologically in phase with the planting environment, planting commenced the second week in July,and completed by August 1st. A total of 20,000 seedlings were planted in the Northern Region, 10,000 seedlings/ site. Survival remains within 99 % range after four growing seasons, in spite of the first two droughty growing seasons. The rate of growth has been excellent over the past four years, with an average total height growth of 1.6 meters. Because of the rapid rate of growth,the planted jack pine stock has managed to stay ahead of competing grasses, aspen and common perennials of the Boreal forest.

Table 1. Four different container nursery (greenhouse) environments

Environment (type)	Date (month.)	Supp. Light / Intensity (type) ($\underline{u}Es^{-1}m^{-2}$)	Nutrient (N-P-K)	Culture Period (weeks.)
A ■ crop 1 dp + open air	1-5 6	fluorescent/low-variable local climate	Mgrs. pref. Mgrs. pref.	Growth phase-16 Harden. phase-4
B ■ crop 2 dp + extended grhse.	6-9 10-11	fluorescent/low-variable fluorescent/low-variable	Mgrs. pref. Mgrs. pref.	Growth phase-16 Harden phase- 6
C ■ Tree Imp. + open air	2-4 5-7	HPS @400 watts/3m^2 =300 local climate	229-29-154 45-99-165	Growth phase-11 Harden. phase-9
D ■ Proposed opt. s/dp + open air	3-7 8	HPS@ 400 watts/6m^2 =150 local climate	Mgrs. pref. Mgrs. pref.	Growth phase-14-16 Harden. phase- 4

LEGEND
dp : double poly. greenhouse cover
sp : single poly. greenhouse cover
HPS : high pressure sodium light
N-P-K : nitrogen- phosphorus- potassium @ ppm

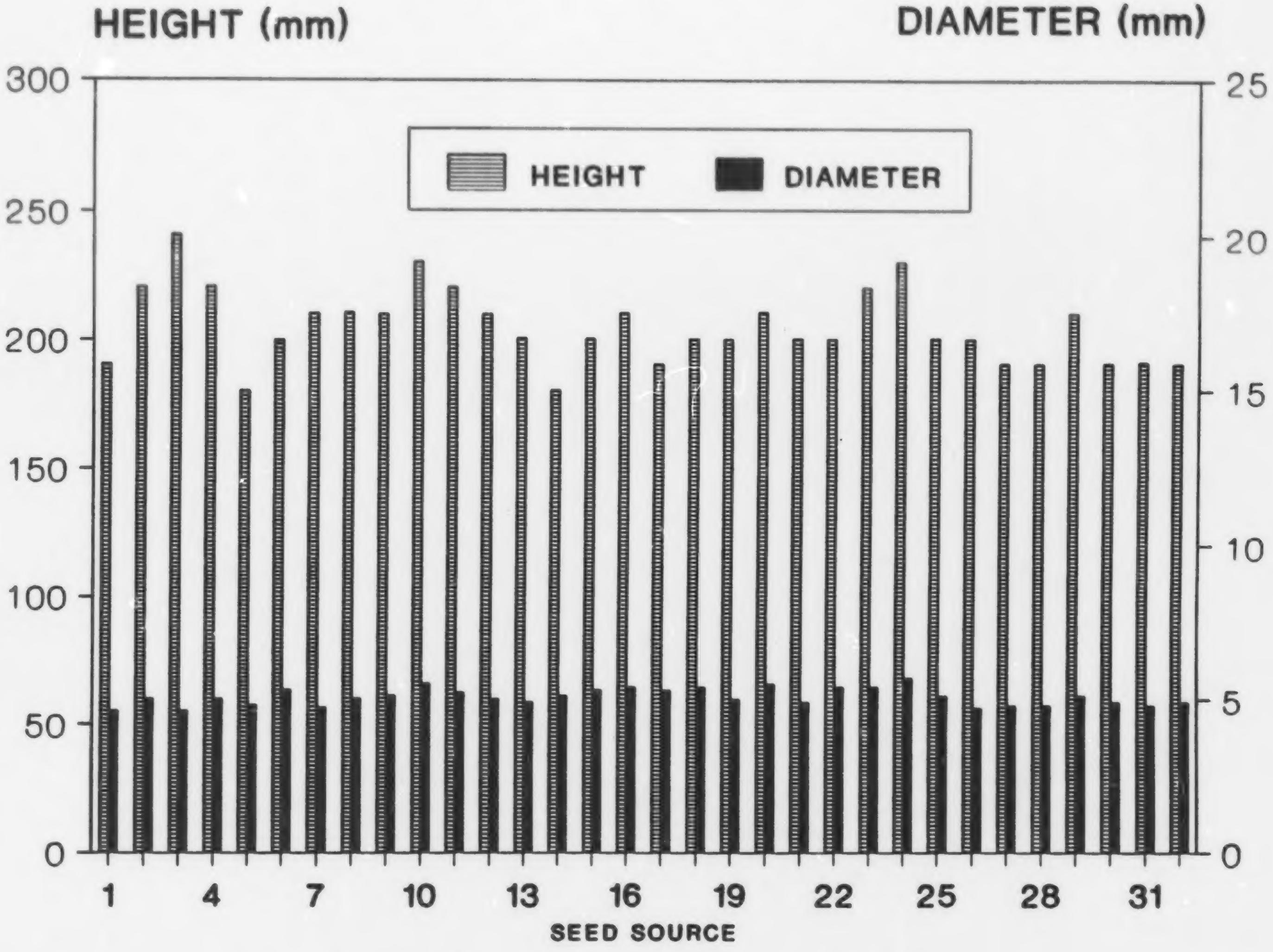


Figure 2. Average height and diameter at planting

Figure 3. is an illustration of the present two crop rearing time- frame in practice by some container nurseries, including Pineland. Superimposed is a time-frame for a proposed one-crop option, and a two-crop option for container nurseries that have access to coldroom storage and are prepared to practice extended greenhouse culture. The proposed one- crop option time-frame, D ▮, shown in **Table 1**, can be grown economically. Lets examine some of the most relevant nursery **costs** and **benefits** based on the proposed rearing option. In **Table 2.**, key cost factors that would require investment or operational change are listed with, monetary and non-monetary benefits which may not be relevant to all operations.

Table 2. Nursery costs and benefits for the proposed rearing option

▮ COSTS:

- Supply/install HPS light @400 watts/6m^{2}/=\$300/10 crops = \$5/1000 sdlgs.
- Electrical cost @ 150 $\underline{u}$Es-^{1} m-^{2} /6000 seedlings = ------ \$26/1000 seedlings
- Install and operate water cool pads @ $12/6000 seedlings = $2/1000 seedlings
- Acceptance of greenhouse up-grading recovery costs through seedling quality

▮ BENEFITS:

- Longer natural daylight hours at ---------------------------- no extra cost
- Higher natural light intensity at ---------------------------- no extra cost
- Reduced heating cost at approximately -------------------$40/1000 seedlings
- Reduced use of chemicals for treatment of infectious diseases on seedlings
- Reduced hazard to staff due to:-------------------------- less chemical use
- Reduced labour costs due to:---------------------------- less stock culling
- Higher physiological tolerance of seedlings at shipment = to less vulnerable seedlings
- Incentives from silvicultural operations-------------------------

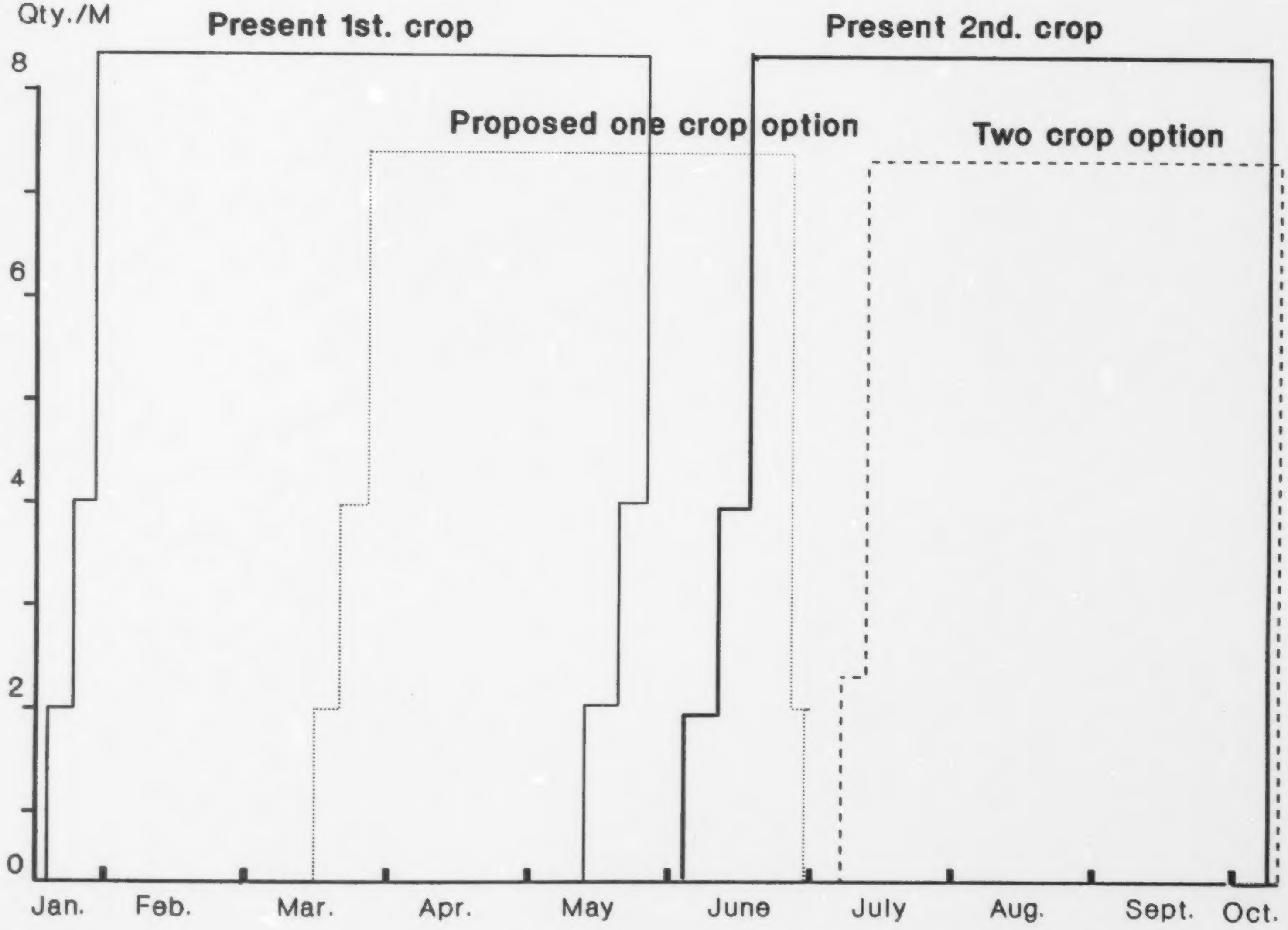


Figure 3. Present and proposed time-frame for rearing conifer seedlings.

To keep common goals in focus, I have listed in **Table 3.**, the key spin-off factors of the proposed rearing option as they pertain to silvicultural costs and benefits. This also allows you to see what impacts nursery operations have on silvicultural operations. In this introductory presentation I will not go into detail on costs and benefits for silviculture.

Table 3. Silvicultural costs and benefits for the proposed rearing option

▮ COSTS:
- Re-allocation of planting costs to up-grade greenhouse facility
- Re-examine planting site preparation and vegetation management
- Infringement on traditional renewal methodology
- Acceptance and implementation surprises

▮ BENEFITS:
- More flexible planting time-frames to re-schedule in emergencies
- Greater number of LATE SUMMER PLANTING DAYS
- Higher stock quality provides more assurance for forest renewal
- Higher survival rate translates into 10-20% saving in renewal costs
- Compatible stock maintains rapid growth rate with on-site vegetation during early critical years.

Now lets look at the time-frame for the proposed one-crop rearing and planting option, **Figure 4.** This figure illustrates how nursery and silviculture operations fit together. The 40-day planting option certainly adds flexibility to the planting program. **Figure 5.**,illustrates a comparison of a entire current season of current planting time-frames practised in both Eastern and Northern forest regions in Manitoba including a proposed LATE SUMMER PLANT. In addition to benefits listed in **Figure 3.**, consider the advantages of fewer planters well trained planters translated into a more attractive employment period. The impact of spring fire season, late springs and adverse weather has less impact on the longer late summer planting time-frame than the current spring planting program. Most important, the planting stock is physiologically hardier because terminal buds have been set. Not shown in the planting time-frame, the LATE SUMMER PLANT coincides with root elongation which takes place immediately after the proposed planting time-frame. There is ample time for root elongation to take place before freeze-up as seedlings go into dormancy, in phase with seasonal weather. To reduce most after planting risks till free to grow stage, I view the proposed rearing and planting option more compatible in achieving rapid growth rate during the early critical years.

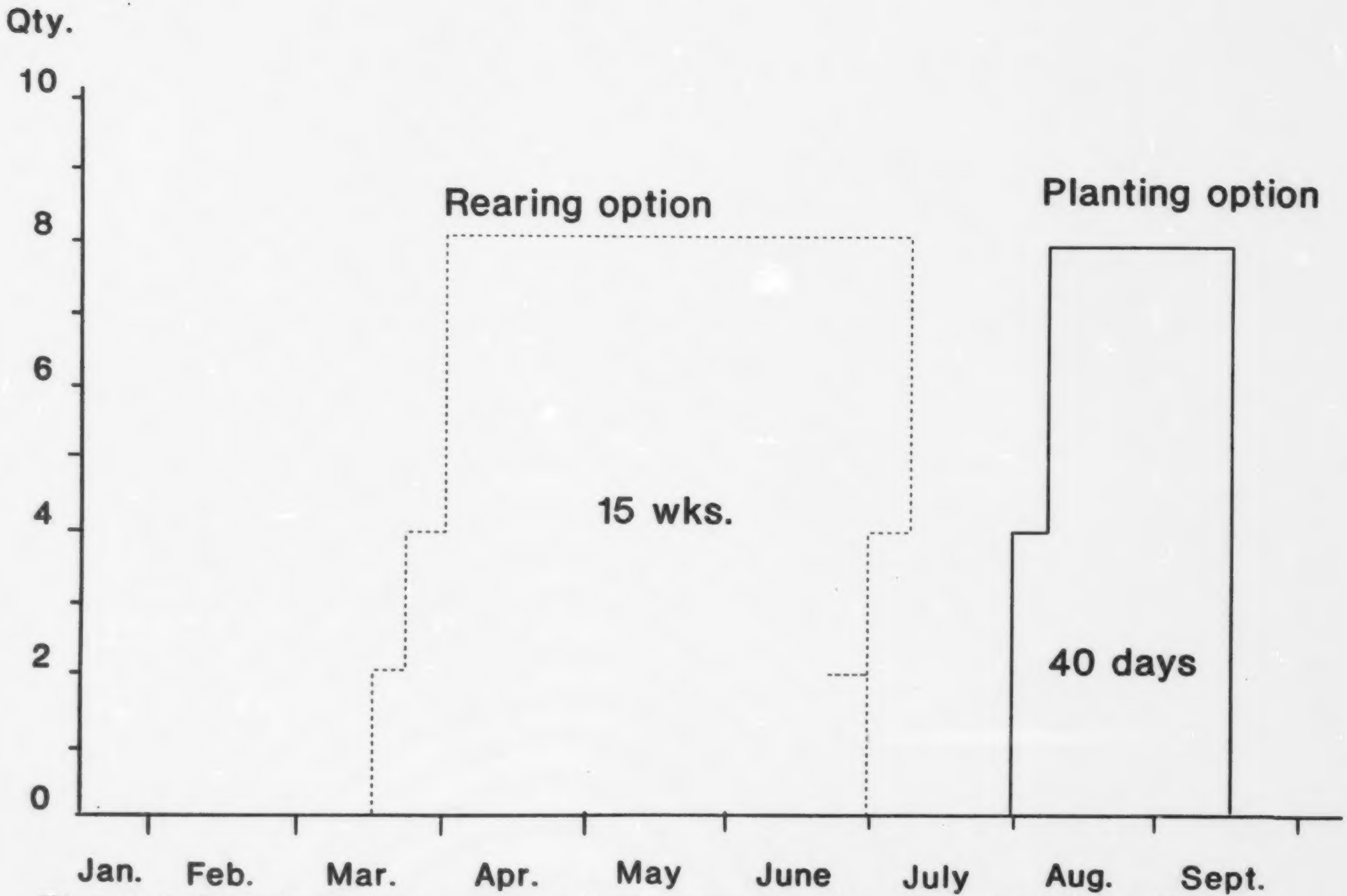


Figure 4. Timeframe for proposed one crop rearing and planting option

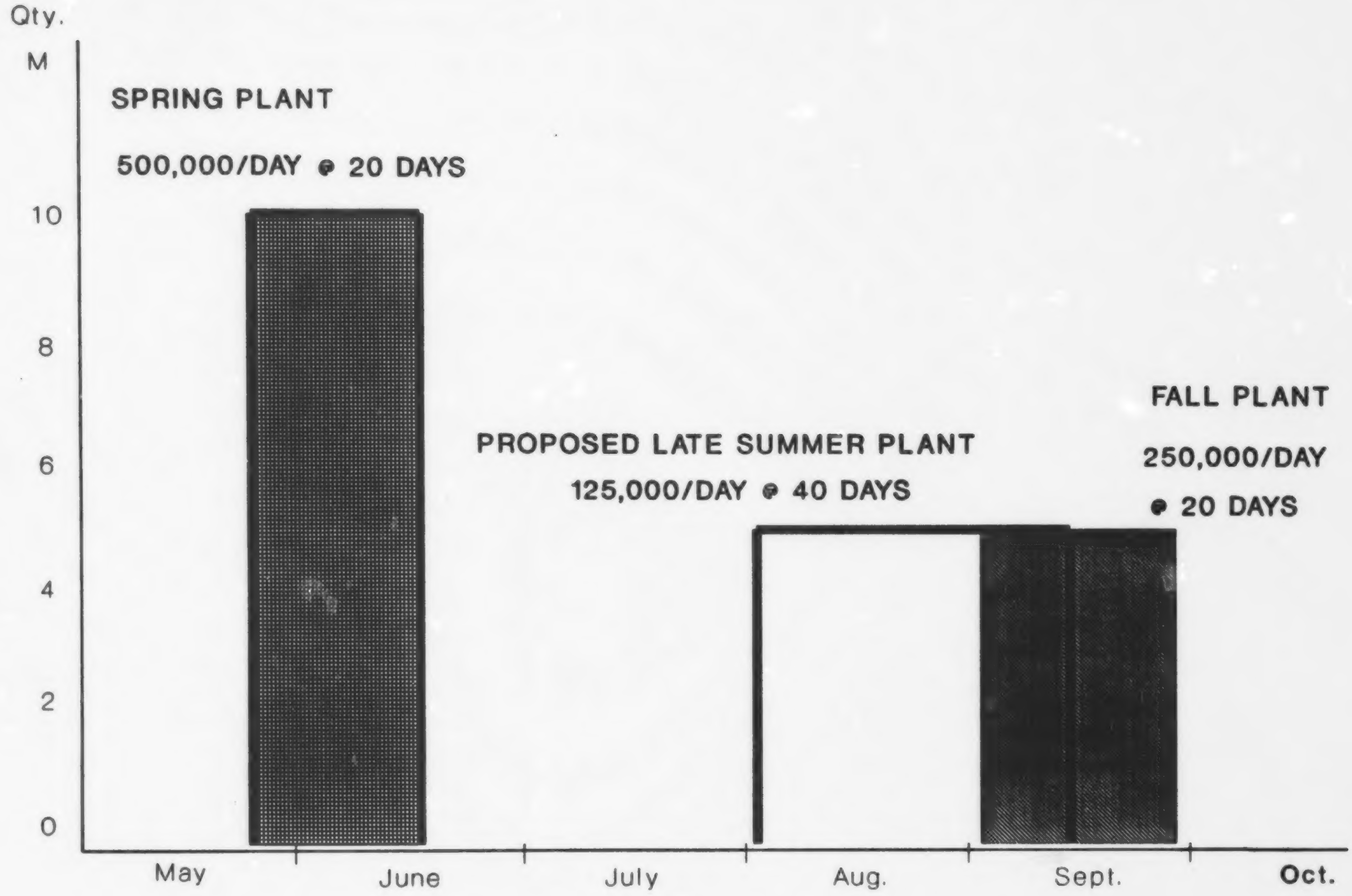


Figure 5. Planting time-frames for container reared seedlings.

ONTARIO MINISTRY OF NATURAL RESOURCES

NURSERY INVENTORY PROGRAM

Thom McDonough - Nursery Stock Culture Specialist

To quote directly from Armson and Sadreika's Forest Tree Nursery Soil Management and Related Practices,

> "The purpose of any inventory is to obtain an estimate of the number of trees or plants, in total or more usually by age class or other designation."

Before providing an overview of the new MNR nursery inventory system that was recently developed, let me provide some background for those of you who are unfamiliar with the Ontario scene.

Our nurseries are, or rather were, administered by the Region that the particular facility was located in. In a sense, these production facilities were autonomous within the region with the only exception being our four southern Ontario nurseries where some seedling production for other regions did take place. Superintendents were asked to produce set targets and were, in most cases, allowed complete inventory control to meet these production levels. A general feeling pervaded that it was more sinful to be under target than to be over it. As a result, any bias in seedling production would be towards making sure that there were sufficient trees available to meet allocation requirements.

With the advent of the private grower production for container stock, and an ever decreasing funding availability, the surpluses of unallocated stock that could be carried by the nursery, became less and less.

Due to increased interest in tree seedling production as the public became more environmentally conscious,nurseries were finding it much more difficult to dispose of excess stock. The nurseries were required to be more aware of the numbers of seedlings that were being carried and needed "up-to-date" information on the loss/survival expectations for the various stock types. This fine tuning of production levels re-emphasised the need for a more sophisticated inventory system.

The need for accurate numbers was not only felt at the nursery level but in the Nursery Stock Management Unit as well. A data collection program called the Stock Production Data Management System or SPDMS for short was only answering part of the need for nursery inventory statistics and this information was supplemented by having the nurseries send principle inventories, typed on standard forms, to the

Nursery Stock Management Unit. There was some duplication of effort in this practice, and so a Systems Officer was hired to come up with an inventory system that could utilize the new hand-held, electronic, field data recorders and produce the information needed at main office while still providing the nurseries with data they required.

Somewhere in the midst of this program development, the inventory program got caught up in the development of a complete nursery information system. As a result of this, the inventory system that was developed is considered temporary but is probably quite representative of what the final version will be like.

Program Description

The Nursery Inventory System (NIS) provides the ten provincial nurseries with the ability to calculate their current and projected ship inventory, and report this information to the Nursery Stock Management Unit.

To use the NIS, a Microflex MS-DOS DAP unit with a minimum of 1.2 M of memory and a MS-DOS PC are required. A manual of instructions was also produced by the system programmer.

The NIS has two separate functions, being the Inventory and the Stock program.

The Inventory, or Data Collection program, is used on the DAP unit to accumulate sample counts in order to calculate the inventory for every stock number at the nursery.

Once the stock number has been inventoried, the information is down-loaded from the DAP to the PC. The Stock Program is used on the PC to enter additional information for each stock number as well as to generate the inventory report.

The program for the DAP unit is conveniently down loaded from the PC to the DAP and the nursery staff are ready to conduct their inventory sampling.

The Inventory Program includes the following functions:

ENTER COUNTS (Figure 1 & 2)

-allows you to enter the sample field counts for a stock number. The machine on the initial start up will also ask for specific information:

UPDATE COUNTS (Figure 3)

-allows you to update a stock number's sample field counts.

FIGURE 1

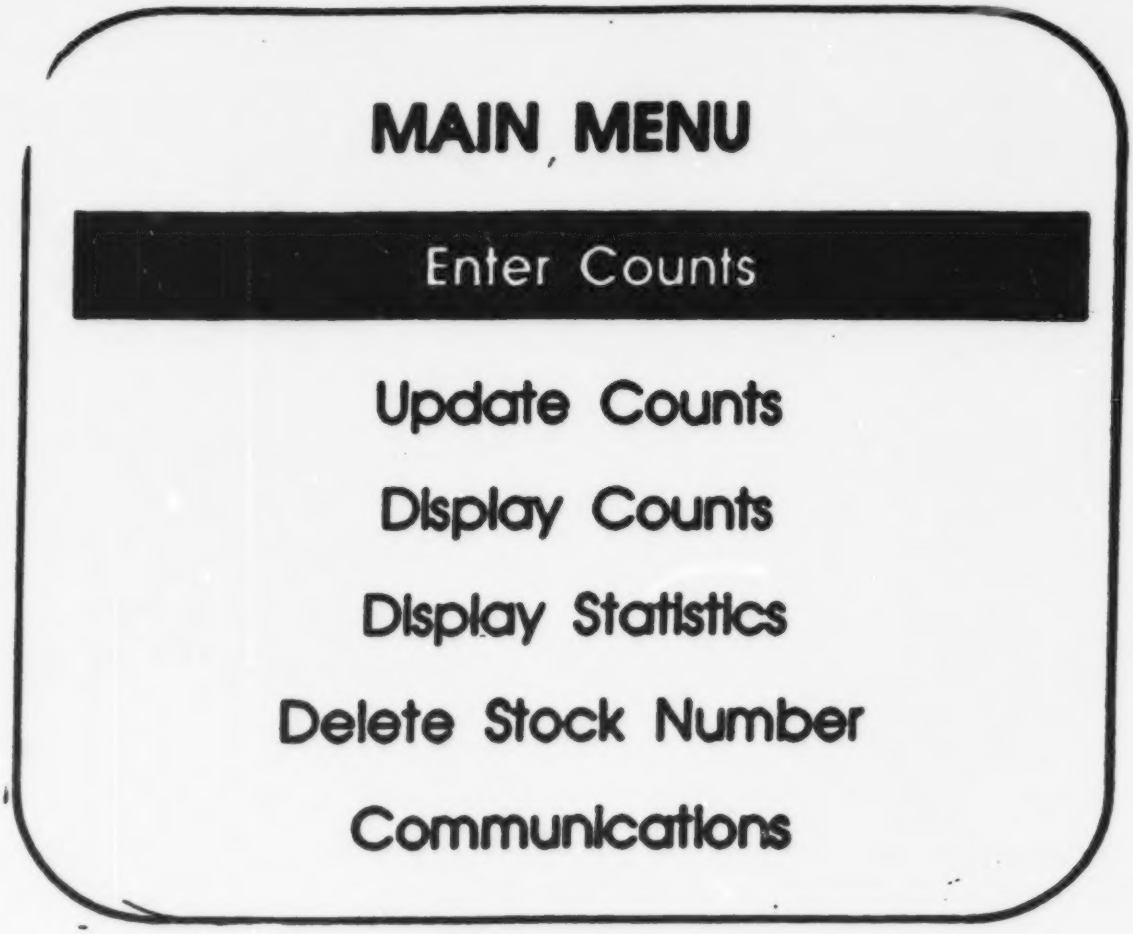
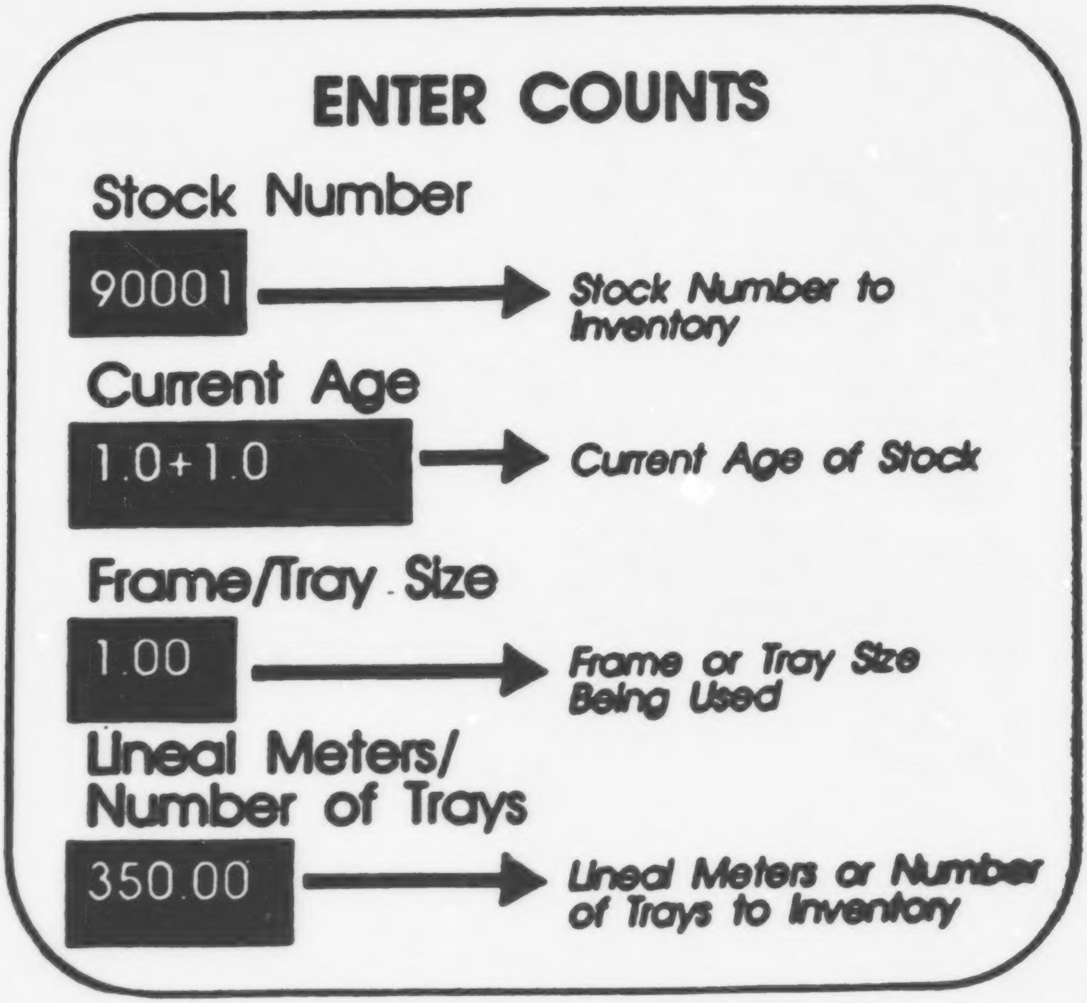

MAIN MENU
Enter Counts
Update Counts
Display Counts
Display Statistics
Delete Stock Number
Communications

FIGURE 2



ENTER COUNTS

Stock Number

90001 → *Stock Number to Inventory*

Current Age

1.0+1.0 → *Current Age of Stock*

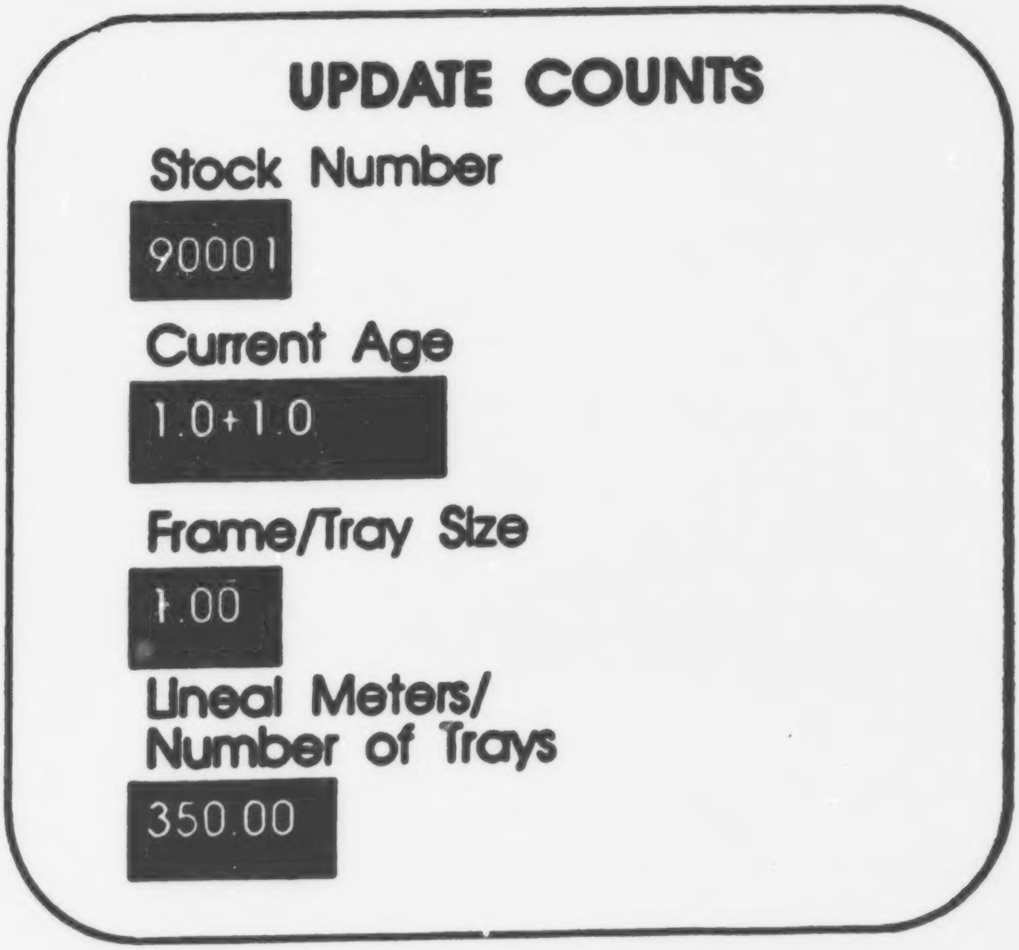
Frame/Tray Size

1.00 → *Frame or Tray Size Being Used*

Lineal Meters/
Number of Trays

350.00 → *Lineal Meters or Number of Trays to Inventory*

FIGURE 3



UPDATE COUNTS

Stock Number: 90001

Current Age: 1.0+1.0

Frame/Tray Size: 1.00

Lineal Meters/ Number of Trays: 350.00

DISPLAY COUNTS (Figure 4)

-allows you to display a stock number's counts and the total value for each plot.

The DAP unit will first of all ask for the entry of a particular stock number for the display of the counts entered under that stock number.

DISPLAY STATISTICS (Figure 5)

-this allows you to view the various statistics needed to determine whether more sample counts are necessary to meet the required percent error. This display is again prompted through the selection of a particular stock number.

DELETE STOCK NUMBER

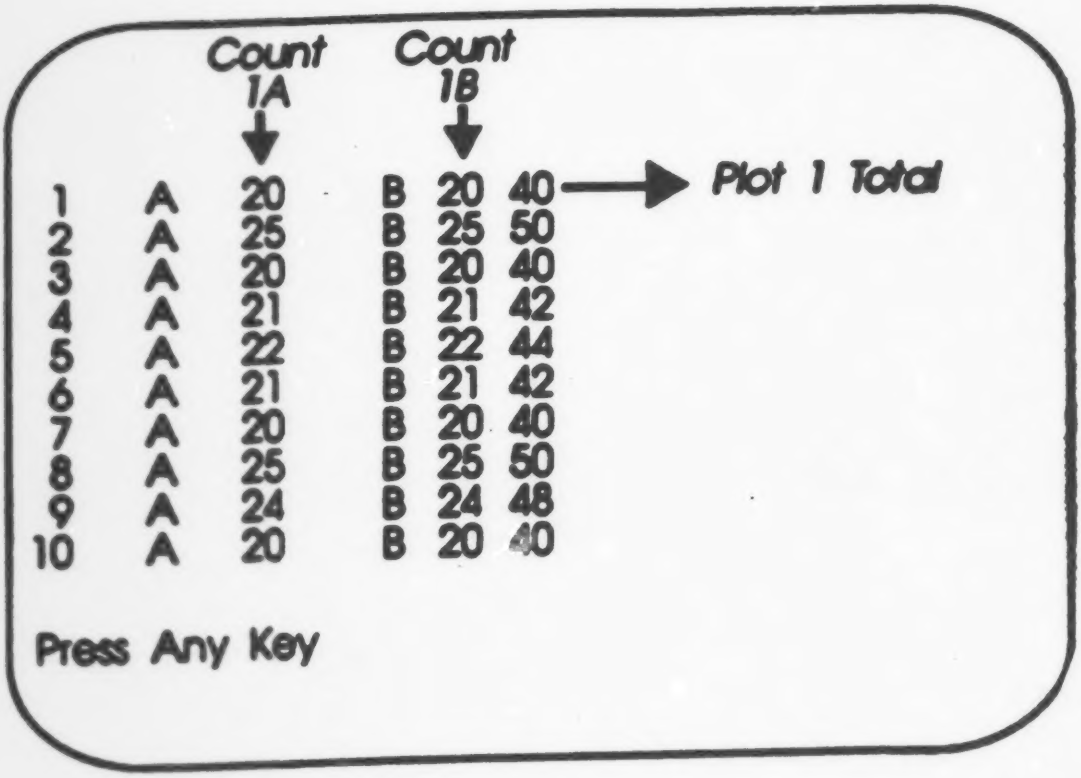
-allows for the removal of a stock number and all of its associated counts from the DAP.

COMMUNICATIONS

-allows the user to establish communications between the DAP and the PC for either the data transfer or for the programming of the DAP unit.

The Stock Program includes the functions listed in Figure 6. This part of the inventory program is used on the nursery

FIGURE 4

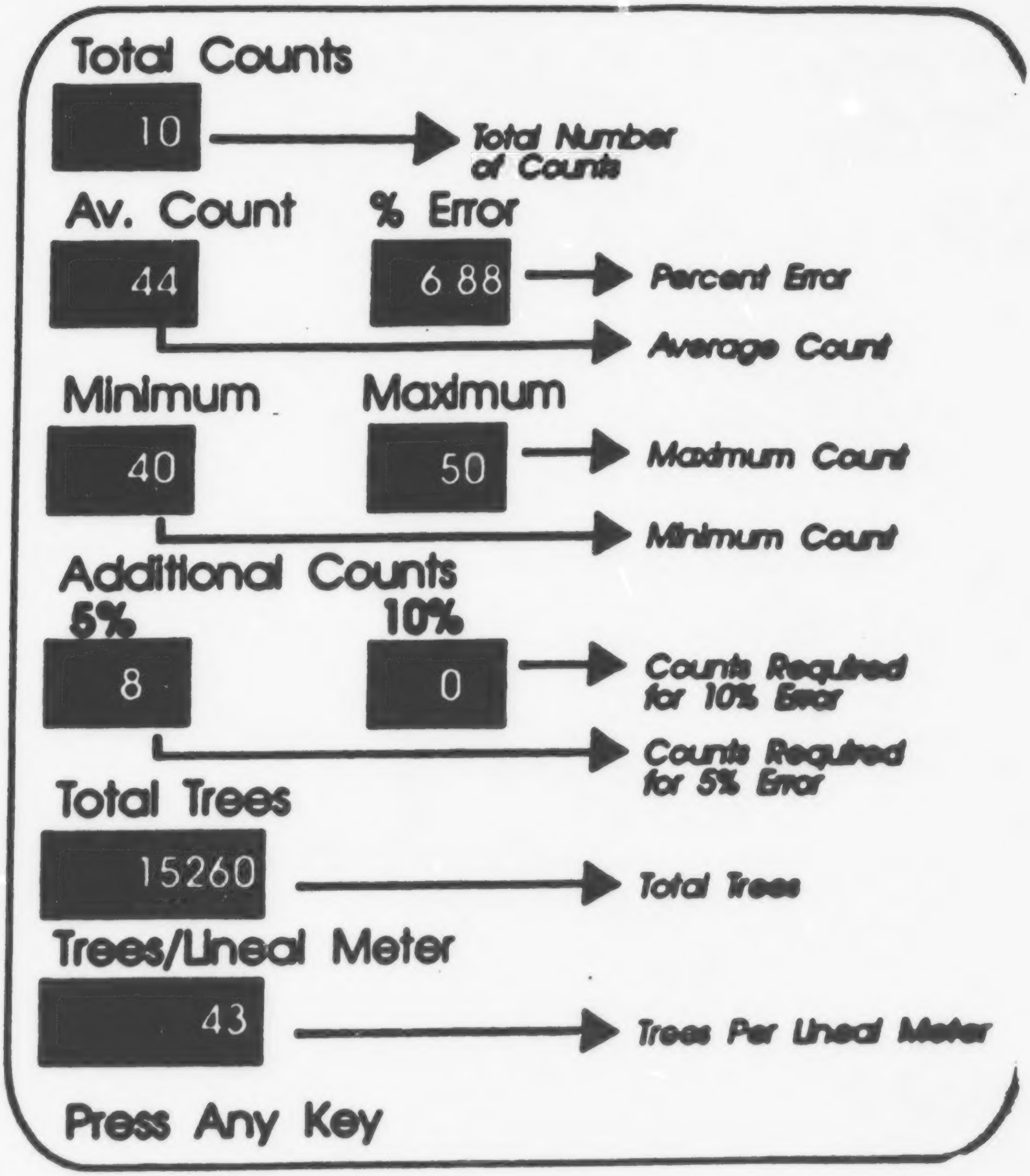


Count 1A
Count 1B
Plot 1 Total

```
1    A   20    B  20  40
2    A   25    B  25  50
3    A   20    B  20  40
4    A   21    B  21  42
5    A   22    B  22  44
6    A   21    B  21  42
7    A   20    B  20  40
8    A   25    B  25  50
9    A   24    B  24  48
10   A   20    B  20  40

Press Any Key
```

FIGURE 5



Total Counts
10

Av. Count
44

% Error
6 88

Minimum
40

Maximum
50

Additional Counts
5%
8
10%
0

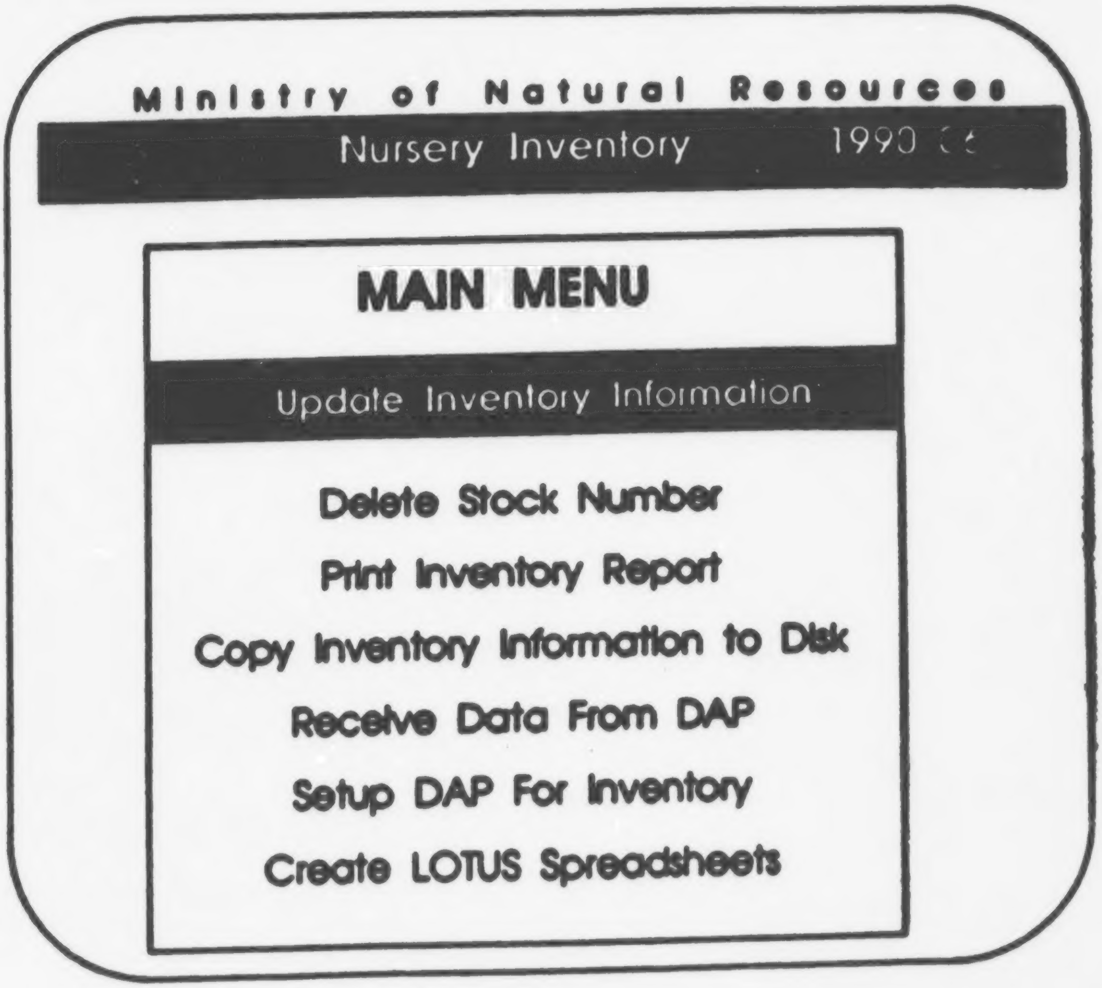
Total Trees
15260

Trees/Lineal Meter
43

Press Any Key

Total Number of Counts
Percent Error
Average Count
Maximum Count
Minimum Count
Counts Required for 10% Error
Counts Required for 5% Error
Total Trees
Trees Per Lineal Meter

FIGURE 6


Ministry of Natural Resources
Nursery Inventory
1990 06
MAIN MENU
Update Inventory Information
Delete Stock Number
Print Inventory Report
Copy Inventory Information to Disk
Receive Data From DAP
Setup DAP For Inventory
Create LOTUS Spreadsheets

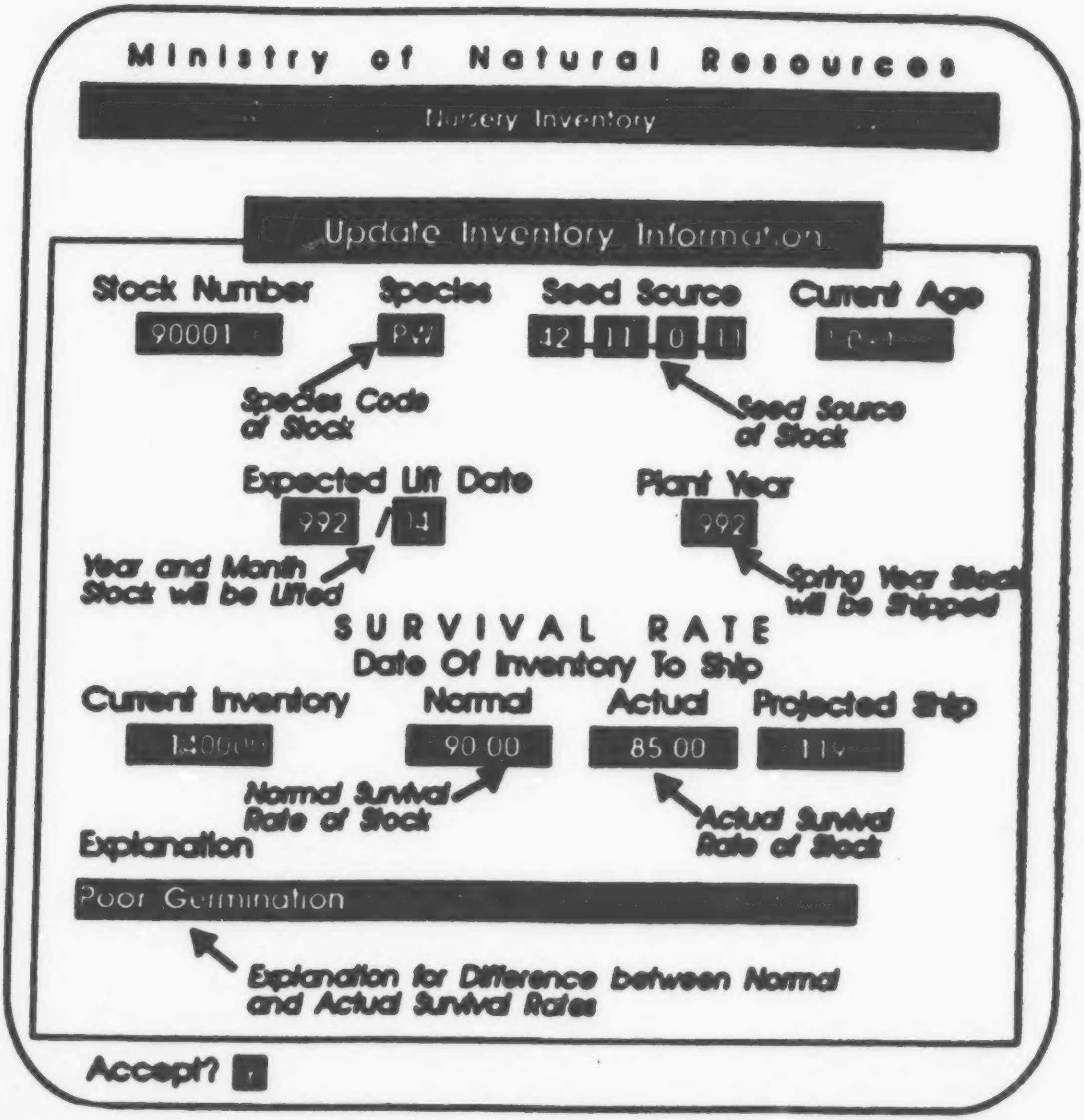
computer and is responsible for the generation of the inventory spreadsheets.
Figure 7 illustrates the screen where the extra data relevant to the inventory is appended.

The Nursery Stock Management Unit is particularly interested in any deviation from the historical loss/survival percentages that would be entered in the "Normal" field. When a deviation does occur, and this is up to the discretion of the Superintendent, then an explanation is required.

The program produces a Lotus spreadsheet that is similar to that represented in Figure 8. This and another spreadsheet showing the counts can be manipulated according to the needs of the individual nursery.

One of the concerns that is still on-going is that of cull estimation. Through a series of audits that were carried out on MNR nurseries, it was found that the setting of cull estimates can be a very arbitrary procedure, despite the existence of good loss/survival historical data. Many of the cull assessments have been described as the "boot scuff and spit" assessment methods. The result of this arbitrary setting of loss was quite often a surplus of seedlings, or what we now call, positive production variance.

FIGURE 7



Ministry of Natural Resources

Nursery Inventory

Update Inventory Information

Stock Number: 90001
Species: PW
Seed Source: 42 11 0 11
Current Age: [illegible]
Expected Lift Date: 992 / 14
Plant Year: 992

SURVIVAL RATE
Date Of Inventory To Ship

Current Inventory: 1400[illegible]
Normal: 90.00
Actual: 85.00
Projected Ship: 11[illegible]

Explanation: Poor Germination

Accept? y

Species Code of Stock
Seed Source of Stock
Year and Month Stock will be Lifted
Spring Year Stock will be Shipped
Normal Survival Rate of Stock
Actual Survival Rate of Stock
Explanation for Difference between Normal and Actual Survival Rates

FIGURE 8

1990/08/06.

Kemptville Nursery
INVENTORY REPORT

Stock Number	Species	Seed Source	Current Age	Expected Lift Date	Plant Year	Current Inventory	% Error	SURVIVAL RATE Date Of Inventory	To Ship Actual	Projected Ship
90001	Or	52-52-0-00	1+0	1991/04	1991	52266	5.4	0.00	65.00	33972
90002	Or	52-00-0-00	1+0	1991/04	1991	51571	9.4	0.00	65.00	33521
90003	Or	52-56-0-00	1+0	1991/04	1991	54394	7.9	0.00	65.00	35384
90004	Or	52-60-0-00	1+0	1991/04	1991	20566	9.1	0.00	65.00	13367
90005	Or	62-70-0-00	1+0	1991/04	1991	63472	7.8	0.00	65.00	41256
90006	Cw	52-52-0-00	1+0	1993/04	1993	53836	20.7	0.00	37.20	20026
90007	Cw	62-60-0-00	1+0	1993/04	1993	2977782	13.3	0.00	37.20	1107734
90008	Sn	52-56-0-00	1+0	1993/04	1993	9595	.20.2	0.00	52.00	4989
90009	Sn	62-61-0-41	1+0	1993/04	1993	804900	9.8	0.00	52.00	418548
90010	Sw	62-64-0-22	1+0	1993/04	1993	2202245	5.7	0.00	20.40	449257
90011	Sw	52-56-0-00	1+0	1993/04	1993	111382	14.9	0.00	20.40	22721
90012A	Sw	62-62-0-41	1+0	1992/04	1992	42958	10.1	0.00	51.90	22298
90013	Sw	62-64-0-22	1+0	1992/04	1992	342009	7.6	0.00	51.90	177502
90014	Sn	62-61-0-41	1+0	1992/04	1992	407106	7.0	0.00	52.00	211695
90015	Sn	62-61-0-41	1+0	1992/04	1992	539682	4.4	0.00	52.00	280634
90016	Pr	62-60-0-00	1+0	1992/04	1992	102600	20.3	0.00	48.00	49248
90017	Pr	62-60-0-00	1+0	1992/04	1992	474292	10.8	0.00	48.00	227660
90018	Pw	62-60-0-00	1+0	1993/04	1993	1769394	6.3	0.00	47.20	835153
90019	Pw	62-60-0-00	1+0	1993/04	1993	201538	8.8	0.00	47.20	95126
90020	Pw	52-60-0-00	1+0	1993/04	1993	122760	10.1	0.00	47.20	57942
90021	Pw	62-60-0-00	1+0	1993/04	1993	293159	9.1	0.00	47.20	138371
90022	Sn	62-61-0-41	1+0	1993/04	1993	949235	8.6	0.00	52.00	493602
90023	Pw	62-60-0-00	1+0	1993/04	1993	585561	8.3	0.00	40.10	234809
90024	Pw	62-60-0-00	1+0	1993/04	1993	16848	28.4	0.00	40.10	6756
90025	Sw	62-60-0-00	1+0	1992/04	1992	336424	7.0	0.00	51.90	174085
90026	Pw	62-60-0-00	1+0	1993/04	1993	377986	7.4	0.00	47.20	178409
90027	Pr	62-60-0-00	1+0	1992/04	1992	333661	11.2	0.00	48.00	160157
90028	Pr	62-60-0-00	1+0	1992/04	1992	77480	7.2	0.00	48.00	37190
90029 1	Pw	52-56-0-00	1+0	1993/04	1993	634702	6.7	0.00	47.20	299579
90030 2	Pw	52-56-0-00	1+0	1993/04	1993	589453	5.6	0.00	47.20	278221
90031 3	Pw	62-60-0-00	1+0	1993/04	1993	493887	3.8	0.00	47.20	233114
90032 4	Pw	62-60-0-00	1+0	1993/04	1993	467175	5.2	0.00	47.20	220506
90033	Pw	62-60-0-00	1+0	1993/04	1993	291242	4.4	0.00	47.20	137466
90034	Pw	52-56-0-00	1+0	1993/04	1993	154144	10.2	0.00	47.20	72755
90035	Sw	62-60-0-00	1+0	1993/04	1993	2319431	6.9	0.00	38.00	881383
90036	Sw	62-61-0-41	1+0	1993/04	1993	318520	7.9	0.00	20.40	64978
90037	Sw	62-61-0-41	1+0	1993/04	1993	559659	7.2	0.00	20.40	114170
90038	Sw	61-62-0-41	1+0	1993/04	1993	66387	10.5	0.00	38.00	25227
90039	Sw	62-61-0-41	1+0	1993/04	1993	136944	10.1	0.00	38.00	52038
90040	Sw	62-61-0-41	1+0	1993/04	1993	122340	13.2	0.00	20.40	24957

The Nursery Stock Management Unit has reviewed a number of procedures that nurseries are employing to determine cull levels. None of the methods are statistically sound as the sample variability would require that an inappropriate number of samples be taken to determine an accurate estimate of the cull percentage. The Nursery Stock Management Unit is participating in a study to determine whether we can get an accurate, operationally possible, estimate of cull. In the mean time we will take cultural steps to reduce cull levels to the point that they are insignificant, hopefully making this a non issue.

For any further information regarding the nursery inventory system, interested individuals could contact:

Supervisor
Nursery Stock Management Unit
Ministry of Natural Resources
P.O. Box 1000
Sault Ste. Marie, Ontario
P6A 5N5

COOL DAY/WARM NIGHT CONDITIONING OF CONTAINER STOCK

John Thorpe - Clearwater Nursery

ABSTRACT

Conditioning black spruce (Picea mariana) with warm temperatures (trial crop) was compared to conditioning with constant cold temperatures (control crop). The temperature trial crop had warm nights until 100% bud initiation occurred then a warm day and night for rapid bud development. The warm night regime resulted in bud initiation 10 days before the cool night control crop. Bud development was quicker for the trial as it reached 100% with needle primordia 17 days before the control crop. Primordia numbers in the trial crop were approximately 60 greater than the control crop. The warm-night trial crop had an index of injury of 3.0 and the cool-night control crop had an index of 1.9 at 33 days of conditioning.

ACKNOWLEDGEMENT

Much of the background information for this report was obtained from research conducted by Mr. Steve Colombo and Kary Odlum, research scientists for the Ontario Ministry of Natural Resources. Information from his work was obtained through conversations between Mr. Colombo and John Thorpe, superintendent at Clearwater Forest Nursery.

INTRODUCTION

A trial with a warm night - cool day temperature regime for conditioning containerized black spruce (Picea mariana) seedlings was attempted in the 1990 current crop. The trial crop was compared with crop conditions using a cool day/night temperature. The current crops were sown in early January and were scheduled to reach a 9cm. shoot height by mid April when conditioning is to start. These crops were scheduled for move-out on June 5 and for shipping on June 20.

The idea of warm nights-cool days has been a topic of discussion among members of the Crop Management Team at Clearwater Nursery. This idea is based on the theory that much of the plant's energy to initiate bud takes place most quickly with warm night temperatures. Bud development is facilitated by using warm temperatures with short day lengths of 14 hours or less (Steve Colombo 1982). During the day when light levels promote photosynthesis, cold temperatures could be used to limit growth and aid in the development of cold-hardiness. In other words, develop bud and cold-hardiness in the spring by helping the night and contesting the day.

The objective of this trial was to answer several questions regarding conditioning black spruce seedlings in the spring with the warm night-cool day temperature regime.

1. Would the seedlings initiate and bud sooner than crops conditioned with cool-night temperatures?
2. Will the rate of bud development increase as indicated by primordia development?
3. Does the warm night regime produce a degree of frost-hardiness comparable to the traditional method of cold-night temperatures?

It should be noted that day temperatures were warmer than expected. Consequently, both crops rarely achieved a day temperature as low as +5 degrees C. The night temperatures are the main variable for comparison in this trial. Favourable results were achieved with warm night conditioning temperatures.

METHODS

Two crops from seed zone 11.8 (Thompson 55°, 48° N latitude 97°, 52° W longitude) were the focus of the trial. Crop #90-C-E2-11.8 was the control crop with cold temperatures, 5°C day and night, and crop #90-C-E4-11.8 was the trial with the warm nights, 12-18°C, and cool days, 5°C.

Once both crops had reached an 8cm shoot height, water only was applied to remove some of the nutrient from our fertilizer regime and a drought stress was started. After 5 days, the crops started to dry so the lights were turned off and growing temperatures were dropped at a rate of 5°C per hour to the prescribed conditioning temperatures.

For the trial crop, temperatures were adjusted twice daily at 8:00 a.m. and at 4:00 p.m. Once the trial crop had achieved 100% bud initiation (BI), temperatures were set for 14-22°C day and night. One week prior to move-out the trial crop temperature was set to a minimum of 5° or outside ambient to acclimatize.

The control crop was maintained at 5° temperature until move-out unless outside ambient exceeded our control capabilities.

Apart from the varying temperatures, the trial and control crops were treated the same. Both crops were drought - stressed until 60% of the crop had reached wilt point and both started conditioning on April 11, 1990. Both crops received the same fertilizers, Peters Brand Conifer Finisher (4-25-35 @ 35 ppm N) until 100% had developed primordia, then Peters Brand Grower (20-20-20 @ 50 ppm N) until shipping. Both crops were moved outside on May 22, 1990. (Note: test trays were placed outside on may 12. On May 13 the temperature dropped to minus 4.9°C with no damage to stock). Shipping occurred on June 13 for the Cool-Night Control Crop and on June 19 for the Warm-Night Control Crop.

Microscope checks for bud initiation and primordia counts were started 2 weeks after start of conditioning. On a weekly basis, 20 samples from each crop were checked until 20 or 21 weeks of age, depending on shipping dates.

Frost test samples were sent out 2 to 3 weeks prior to moveout and were tested until a index of injury of 5% at -10°C was obtained.

A small sample consisting of 4 plastic Multi pot #1 trays (67 cavities per tray) from the trial and control crops were retained to gather information on bud break.

RESULTS

Figure 1 gives an indication of actual temperatures achieved from the start of conditioning until 100% bud initiation was achieved. Crop E2, control, maintained the 5°C (+/- 2 degrees C) temperature for 48% of the time. The other 52% involved higher outside temperatures during the day. Crop E4, trial, had the 5°C held for only 1% of the time from the start of conditioning to 100% bud initiation and the +12 to 18°C night regime for 79% of the time. Daytime temperatures were high in both greenhouses because of mild weather and solar gain, however, the desired night temperatures were achieved. The main variable in this trial, therefore, is the warm night temperatures (+12 - +18 degrees C in E4) vs. the cool night temperature (ambient down to +5 degrees C in E2).

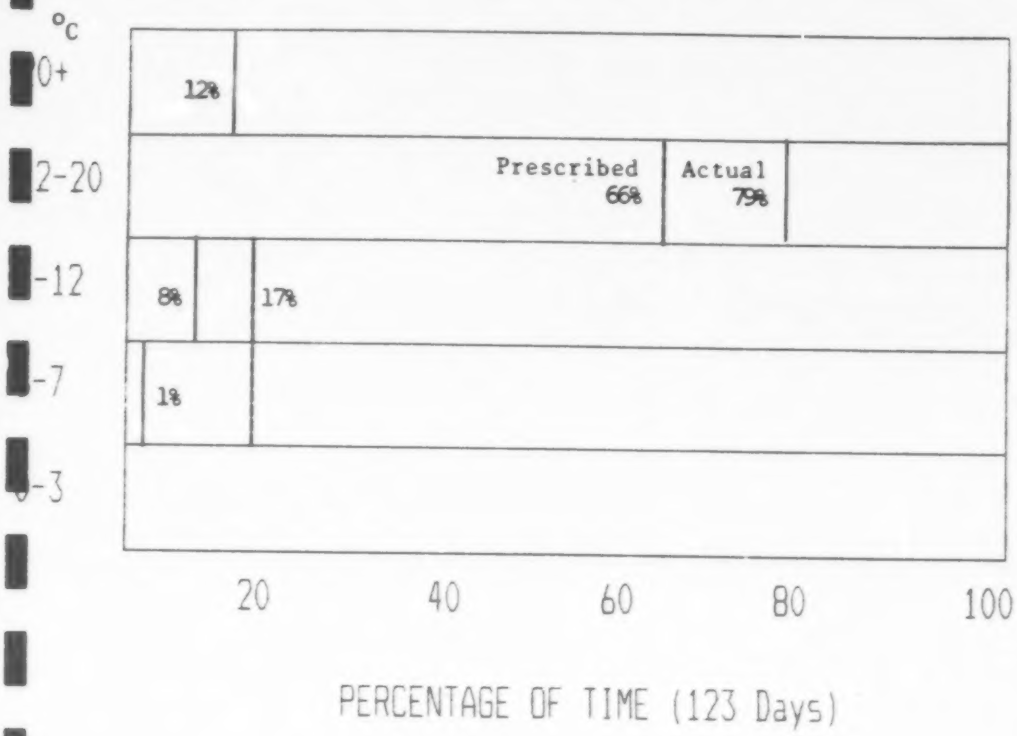
The results for bud development, Table 2, reveal that the control crop @ 5°C reached 100% BI in 33 days and 100% with primordia in 47 days of conditioning. The trial crop reached 100% BI in 23 days and 100% with primordia in 30 days. The trial crop had developed 100% with primordia 10 days before any other crop and 17 days before the control crop.

Table 1. Bud Development For Trial And Control Crop

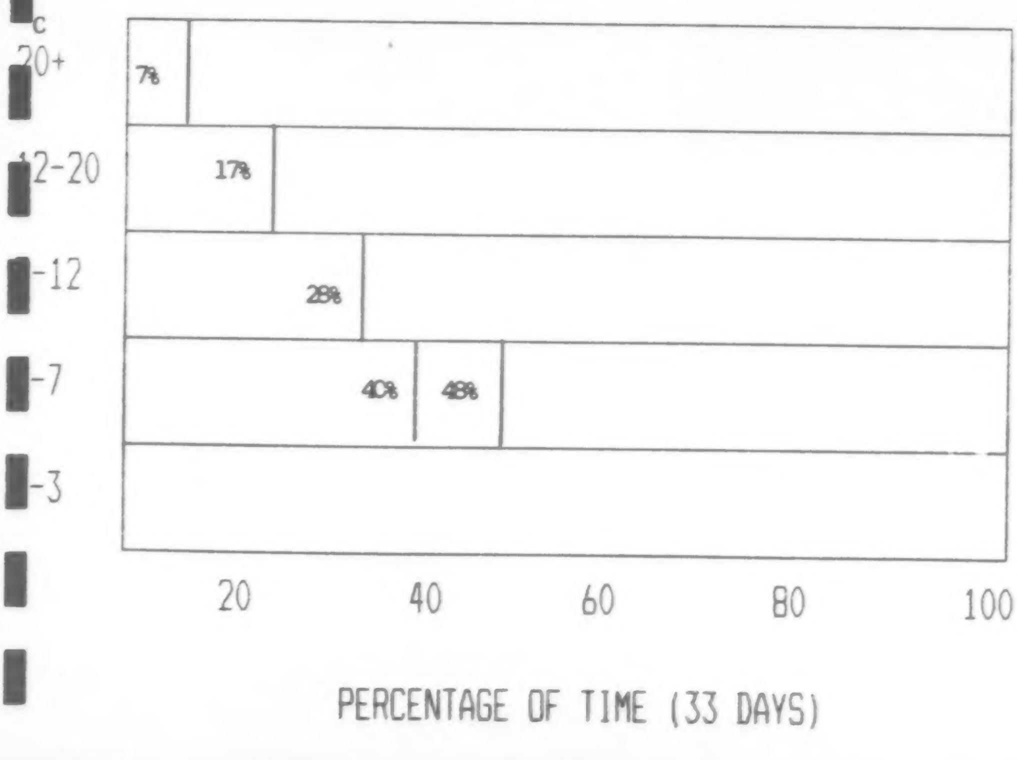
Crop #	Conditioning Start Date	Date of 100% BI	# of Days to 100% BI	Date of 100% Primordia	# of Days to 100% Primordia
Cool 90-C-E2	04-11	05-14	33	05-28	47
Warm 90-C-E4	04-11	05-04	23	05-11	30

The weekly monitoring of bud development for the crops with various conditioning temperatures is shown in Figure 2. The trial crop was the only crop with any indication of BI after 2 weeks of conditioning. At 3 weeks from the start of conditioning the trial crop had 100% BI. For the control crop it took 5 weeks to achieve 100% BI. The trial crop developed primordia sooner and in larger numbers than the control crop.

FIGURE 1: PERCENTAGE OF TIME AT PRESCRIBED AND ACTUAL TEMPERATURES

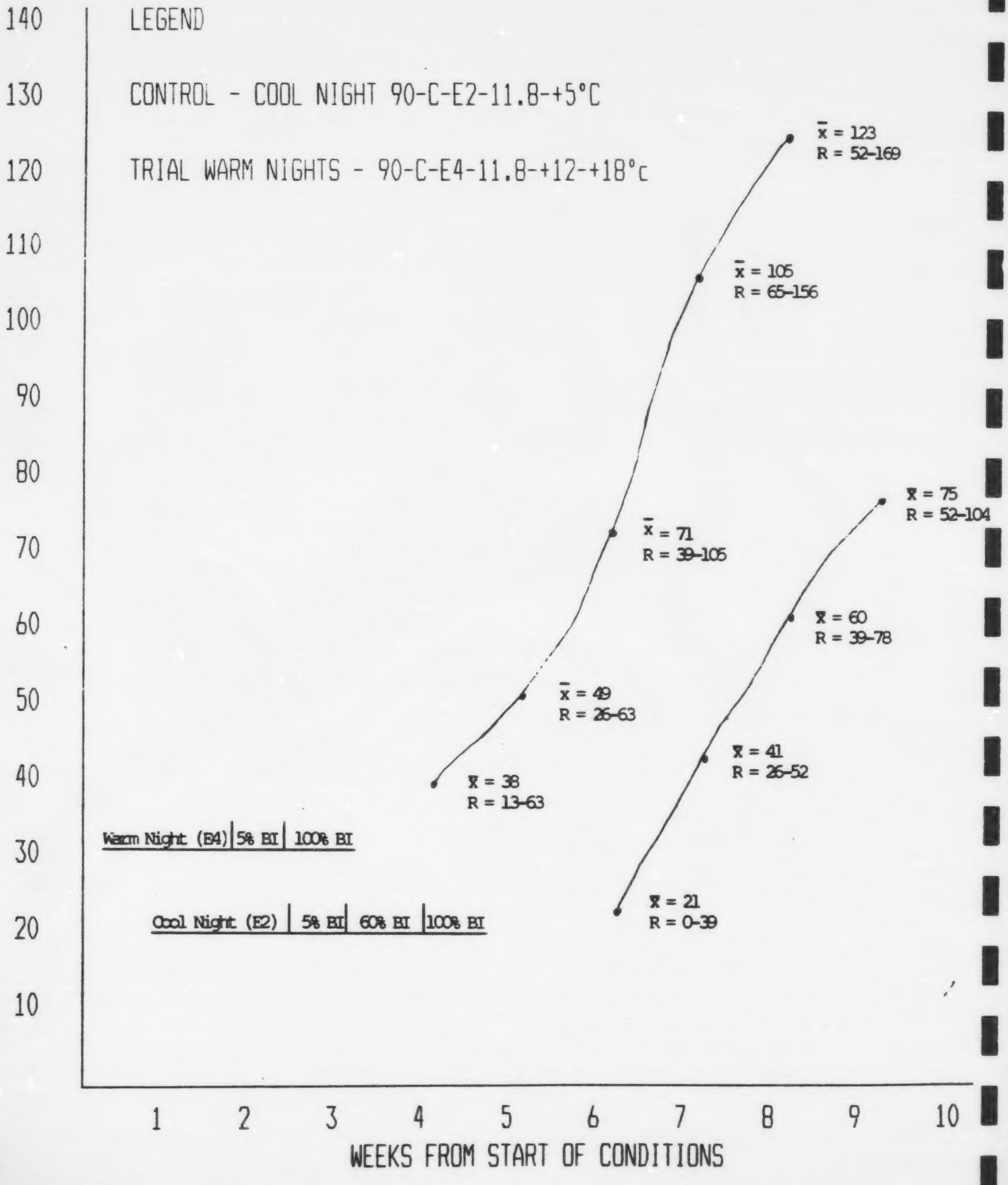


- Crop #90-C-E4-11.8
- Cool Days - 5°C
  Warm Nights -12-18°C
- 23 Days to 100% Bud Initiation



- Crop #90-C-E2-11.8
- Cool Temperatures
- Day and Night - 5°C
- 33 Days to 100% Bud Initiation

FIGURE 2. WEEKLY MONITORING OF BUD DEVELOPMENT FOR 1990 CURRENT BLACK SPRUCE CROPS WITH VARIOUS CONDITIONING TEMPERATURES



The results for the frost-hardiness tests are revealed in Table 2. Frost-hardiness for the control crop was at an index of injury of -0.2 at -5°C test and 1.8 at -10°C test after 33 days of conditioning. The trial crop had an index of injury of 0.0 at -5°C test, 6.3 at -10°C test after 26 days of conditioning and an index of 3.0 at -10° test after 33 days of conditioning.

Table 2. Frost-Hardiness Tests Conducted For 1990 Current Black Spruce Crops

Crop #	Sample Date	-5°C Test Index of Injury	-10°C Test Index of Injury	# of Days
90-C-E2	05-14	-0.2	1.8	33
90-C-E4	05-07	0.0	6.3	26
	05-14	--	3.0	33

DISCUSSION

The ability to maintain the desired temperatures in the greenhouses was limited by high outside ambient temperatures during the day. Since our cooling capacity consists of venting with 2 exhaust fans, outside ambient temperature is the determining factor on the cooling end of our control system (Honeywell Micronic Controller). The heating side of the control system is capable of heating during this time of year which is why the night time range in the warm night - cool day regime was maintained for a high percentage of the time. The difficulty in maintaining this warm night range occurred between 4:00 and 8:00 p.m. Nightly temperature settings were made at 4:00 p.m. when the shift ended. This increase in set point combined with solar heating would elevate temperatures above the 12-18°C range until about 8:00 p.m. when outside temperature was dropping and the sun was setting.

Daylight hours (sunrise to sunset) at the time the trial and control crops started conditioning, April 11, totalled 13.77 hours (Environment Canada, The Pas). The critical photoperiod for trees near Thompson, Manitoba (seedzone 11.8) is estimated to be about 17 hours. Therefore, the photoperiod reduction is favourable for bud initiation. Trees from the northerly seed zones have a higher critical day length (eg. 17 hours for Thompson vs. 16-16.5 hours at The Pas). The warmer temperature in the trial crop did in fact allow for a faster rate of bud development and a higher degree of primordia development.

From Figure 2 it is apparent that more primordia developed in the trial crop. When compared to the control, not only did the trial crop get off to a good start but the slope of the curve is much greater. The trial crop had approximately 60 more primordia than the control crop at any given time after primordia started to develop.

Results are positive for conditioning with warmer temperatures, but there may be a negative side when considering frost hardiness. Although bud seems to initiate more quickly and develop faster, the degree of frost-hardiness may not be as high with warm nights as a crop treated with cold-night temperatures. The frost test results, Table 2, indicate a pattern of slightly higher frost-hardiness levels for crops treated with cold temperature conditioning. The difference is an index of injury of only 1.2 at 33 days of conditioning between the trial and control crops.

CONCLUSIONS AND RECOMMENDATIONS

There seems to be some benefit in using the warm night-cool day temperature regime for conditioning current black spruce crops. The gains may be stated as 1 to 2 weeks quicker bud initiation and 25 to 60 more primordia at any given time after primordia begin to develop.

The negative aspect of conditioning with the trial temperature regime is less frost-hardiness. The difference is small and the tests at similar times after the start of conditioning were below an injury index of 5 (considered the pass-fail mark as derived from research done by Steve Colombo).

With the benefits noticed in this trial, further trials should be done. In future trials more extensive frost-hardiness testing should be conducted to see if less frost-hardiness is a pattern when using warmer conditioning temperatures in a current crop. In the trial, a group of crops (2-4) for each type of conditioning temperature could be started at the same time and conditioned on the same date. Subsequently, we could frost test all crops at the same number of days after conditioning to analyze the relationship between conditioning temperature and frost-hardiness.

It is also recommended that we continue to use seed zone 11.8 for current crops due to its geographic location (approximately 55.5° north latitude). Research data from Mr. Steve Colombo indicates that black spruce seedlings critical day length increases with latitude, so it may be easier to initiate bud with this seed zone as opposed to a more southerly zone.

Achieving shoot height specification was achieved on schedule, almost to the day, for 1990 current crops from the 11.8 seed zone. It is advisable to start this crop as early as possible in January in order to reach height and start conditioning as early as possible. This would ensure not missing the photoperiod trigger for bud initiation.

RECOMMENDATIONS TO IMPROVE CURRENT CROP CONDITIONING AT CPFN

1. For Photo Period

   a) Identify natural photoperiod for the scheduled conditioning period at your nursery.
   b) Identify the critical photoperiod for each seed zone you will be growing. Note: The critical photoperiod will be longer for trees from a more northerly latitude.
   c) Schedule conditioning to occur when seasonal photoperiod is below the critical length or have the resources to afford blackout treatment and possible frost protection.
   d) Provide a 4 to 5 hour reduction in photoperiod at start of conditioning.

2. Frost Hardiness

   a) Use regular frost hardiness tests to identify the earliest safe move-out date for each crop or allow a minimum of 4 weeks past 100% B.I. before moveout.
   b) Identify the degree of frost-hardiness required at your nursery and at outplant site.

3. Look for information on current crop conditioning (there seems to be a shortage of information on this topic).

4. EXPERIMENT on a small scale. You may find potential for gains with current crop conditioning.

Climate and Irrigation Scheduling in a Bareroot Tree Nursery

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Abstract

The Ontario Ministry of Natural Resources, Dryden Tree Nursery has worked with Environment Canada, Bioclimate Section, Applications and Impact Division of Downsview, Ontario to develop a climate-based method of monitoring soil moisture status for Nursery compartments. Integrated into the model is a daily irrigation schedule work order for multiple compartments. The result is S.I.A.M.M. -Soil Irrigation and Moisture Model running on an IBM PC-AT or compatible.

The objective of this presentation is to describe the operation phases of development and in-use practices.

The adopted methodology uses existing technology and can easily be integrated into Nursery management plans and practices. The variability of Nursery soils, species/age classes, climate and staff must be considered when developing the operational aspects of the scheduling model. The need to produce operationally realistic and achievable estimates of irrigation across dynamically changing plant characteristics and users was a priority.

The climate-based model is both efficient and cost effective in terms of human and financial resources required. It is neither labour intensive nor does it impact on the type of crop management options available to the Nursery Manager (e.g. fertilization, pesticide applications, harvesting). The resultant climatic data base and resulting climate/weather sensitivity can be used to better define practices such as water stressing crops, applications of herbicides, fungicides, and understanding productivity, variability and capability.

The basis of most irrigation scheduling techniques have a water budget basis. Simply expressed, this basis is:

$$SMS_i = SMS_{i-1} + (R_{eff} + IRR) - (E_t + D)$$

where SMS_i = soil moisture status on day i
R_{eff} = the effective rainfall (rainfall minus interception and runoff)
IRR = irrigation water added
E_t = actual evapotranspiration
D = water loss due to deep drainage

METHODOLOGY:

For SIAMM, the methodology adopted uses as its basis, the techniques developed by Spittlehouse and Black (1981). The adoption provides daily estimates of the volumetric water content of the root zone. The weather data required to run the model are daily values of maximum and minimum temperature and relative humidity, solar radiation and total rainfall. In addition, parameters of tree height, albedo, roughness, leaf area index, field capacity, and wilting point, drainage, root zone depth, irrigation (flow rate and daily volume), soil bulk density, and the value of the soil moisture status at the startup of the model for a particular location are required.

Evapotranspiration is calculated as the lesser of the atmospheric demand or the soil water supply limited rates. The atmospheric demand is calculated using the Priestly and Taylor approach.

Previously a model with site specific, fixed, calculated/determined parameters had been developed for use within a Tree Improvement Seed Orchard. Building upon this model, the objective was to allow for:

1. Input of the variables rather than hard-coded parameters,
2. Allow for multi-site processing vs. single site,
3. Produce a work order from which irrigation planned and actual would be recorded (i.e. both an output and input document).

In 1988, a central automated base climate station and four outlying climate stations were erected on the Nursery . Mobile and vertical surveys were conducted under high pressure stable synoptic weather conditions to provide a thermal footprint of the Nursery and verify the outlying climate station locations.

Throughout a two-year (1988, 1989) irrigation season, weekly gravimetric samples were collected from five plots per trial compartment for comparison to the derived soil moisture status.

HARDWARE:

Weather Station: Basic instrumentation which will provide the necessary weather data is required. This is variable in sophistication and cost dependent. Preferrably, the components should allow for hourly and daily recording to permit historical retrieval determination in the situation where the model operator is unable to record the data immediately upon the completion of the "day".

Systems: To run multiple locations an IBM PC-AT or compatible with 640K ram and a hard drive is required using MS DOS version 3.3 or greater. A printer is required.
To run a single location, the above or a micro data logger such as the Microflex PC1000 is required. The latter is beneficial if you are travelling to a remote location and wish to process the data without returning to the office.

OUTPUTS:

Once the calibration files (i.e. constants) for each locations have been entered into the model data base, the actual input of the previous daily weather, irrigation and forecasted precipitation values are entered. The model outputs a hardcopy work order (Fig. 1) indicating to the irrigation staff the required volume in millimetres and required minutes of irrigation to achieve the model calculated water needs, with and without forecasted rainfall included. Presentation of the to-date soil moisture and water added (rainfall and irrigation) values against the Nursery determined irrigation threshold range is plotted (Fig. 2). The model water requirement is that to bring the soil moisture status back to 61% of field capacity. The 61% is fixed at this point in time for all locations and species. This allows for a visual assessment of soil moisture conditions from which the work order can be altered if a different management prescription is planned.

OPERATIONS:

1. For each compartment or area, data base calibration details are determined.

Vegetation	1. Tree height (m) 2. Albedo (%) 3. Roughness Co-efficient 4. Leaf Area Index (%)
Soil	5. Bulk Density (g/cm$^{3)}$ 6. Field Capacity (cm^3/cm^3) 7. Wilting Point (cm3/cm^3) 8. Soil Drainage Factor (mm/day) 9. Root Zone Depth (cm)
Mechanical	10. Irrigation Flow Rate (mm/hr/m^2)

STARTUP:

To start up the model, all that is required are:

1. Gravimetric Sample
2. Temperature Max. and Min. for 24 hr. period (°C)
3. Relative Humidity Max. and Min. for 24 hr. period (%)
4. Moisture - precipitation for 24 hr. period
   - irrigation for 24 hr. period (mm)
5. Radiation - solar radiation for 24 hr. period (megajoules)
6. Forecasted Precipitation for 24 hr. period (mm)

DISCUSSION:

From our initial use in 1990 and a review of the 1989 season, we have noted the following.

1. Our heavier organic soils retain additional free water in excess of field capacity. The original methodology did not take into account for available moisture, any of this free water. An adjustment was made in the model to allow available water to exceed field capacity to 150% with all water beyond this point being surplus. This is an important modification as small moisture input/outputs can significantly alter an organic soils soil moisture status.

2. Plotting the weekly gravimetric samples reveals greater variation from the within compartment samples than one would expect. This in turn suggests a need for greater within compartment sampling for bulk density, soil retention curves, and altered irrigation application. The model is estimating the needs for "average" moisture requirements and therefore the input "averages" are critical. Therefore, more sampling or increased stratification of compartments is required to best estimate the "averages" for compartment calibration.

3. Stock growth response to various water application rates will be monitored as use of the model increases. This is essential to understanding the interaction of water management prescriptions and the quality of stock produced. This may require that the water determination be for replacement to a variable interactive level rather than the current 61% of field capacity.

The SIAMM benefits expected to be achieved are:

1. Better stock quality through the timely application and quantity of moisture to promote and sustain growth, induce drought hardiness, reduce favourable microclimate for disease, schedule preventive pesticide application.

2. Schedule manpower effectively through model projections.
3. Provide detailed crop records of moisture conditions and weather data for further linking to crop analysis.

SIAMM is a user friendly, interactive tool. It is approaching an artificial intelligence state. Crystal balling, one can foresee the Nursery Manager inputting crop requirements/management needs and the model estimating water alterations for the varying species, ages, soils, and weather conditions. SIAMM is another tool for the Nursery Manager to use in the production of better quality stock.

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SOIL MOISTURE STATUS REPORT FOR JULIAN DAY= 243

           SOIL   TOTAL                           ADJ.
           MOIST  WATER  IRRIG  FORC.   ADJ.      IRR.    ACT.  ACT.
COMPART.   STAT.  REQ.   TIME   PCPN.   IRR.      TIME    IRR.  PCPN  CREW
NAME       (%)    (mm)   HH MM  (mm)    (mm)      HH MM   (mm)  (mm)  NAME
-------------------------------------------------------------------------

C7-90      45.1    4.0   0 32    0.0    4.0       0 32

W7-90      32.7    7.5   1  6    0.0    7.5       1  6

BO-90      46.7    4.3   0 37    0.0    4.3       0 37

W8-90      35.9    6.3   0 56    0.0    6.3       0 56

C7         44.8    4.1   0 27    0.0    4.1       0 27

W7         32.7    7.5   1  4    0.0    7.5       1  4
-------------------------------------------------------------------------
YESTERDAY'S CLIMATE READINGS

MAX. TEMP.(C)=   29.7  MIN. TEMP.(C)=   12.7

MAX. RH(%)=   92.6 MIN. RH(%)=   31.1

SOL. RADIATION  (mJ/M**2)=   14.11
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FIGURE 1.

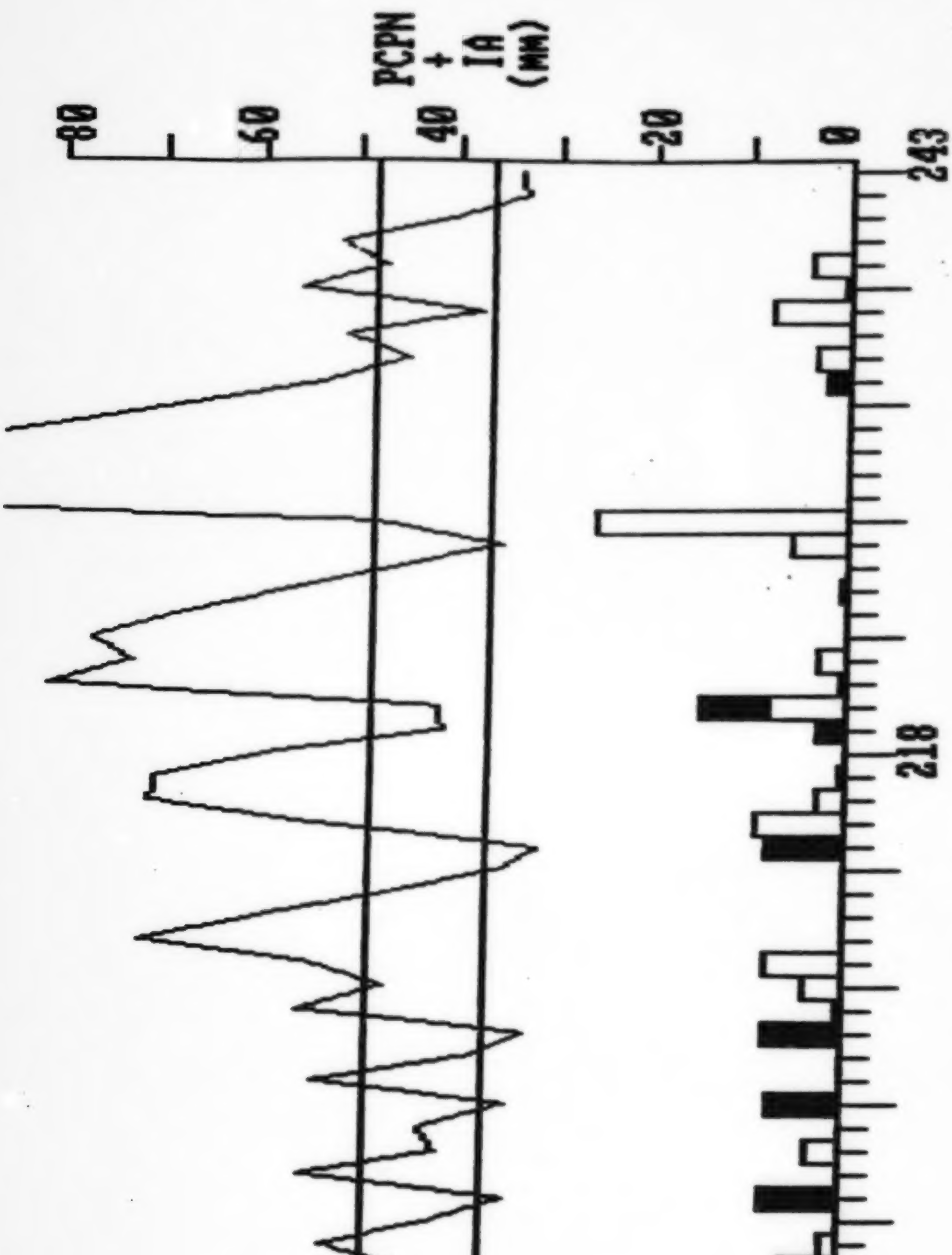
SMS (%)
100
80
60
40
20
0
PCPN + IA (MM)
80
60
40
20
0
194
218
243
JULIAN DAY

FIGURE 2

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QUALITY CONTROL IN GROWING CONTAINERIZED SEEDLINGS

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Forestry Canada
Edmonton, Alberta

INTRODUCTION

Production of containerized seedlings in the prairie provinces has increased sharply in the past two decades. In 1970, approximately one million containerized seedlings were produced but by 1980, there were 25 million. In 1990, current production is projected to be 70 million containerized seedlings. The increase in production has been satisfied, primarily, by the expansion of old facilities and construction of new ones at provincial nurseries and, more recently, by awarding contracts to private growers. Nevertheless, seedling production within the prairies is insufficient to meet the demand. Approximately 12 million containerized seedlings are being produced in British Columbia for planting i Alberta.

The increase in demand for seedlings has outstripped the availability of knowledge in growing them. A two-day course for contract growers of containerized seedlings in Alberta and Saskatchewan has been offered at Edmonton and Prince Albert, respectively. In liaising with public and private growers throughout the Prairies, certain problems, related to seedling growth, keep recurring. These problems have been categorized into six problem areas, namely, 1) Growing Medium, 2) Seeding, 3) Light, 4) Temperature, 5) Water and 6) Fertilizer.

The objective of this paper review the requirements for growing containerized seedlings, as they pertain to the six most commonly encountered problem areas and to reinforce cardinal points for maintenance of quality control within the crop being produced.

PROBLEM AREAS

Growing Medium

The peat used should be course sphagnum and the optimum pH range is 5.0-5.5. If the pH is below 5.0, lime or dolomite should be added to raise pH to the optimum range. When the peat is too acid, i.e. pH below 4.0, poor germination results.

The ratio of coarse - to fine particles, when passed through a 2mm sieve, should exceed 0.5. If the particles are too fine, the peat packs tightly within the lower portion of the container (even in the presence of vermiculite), resulting in poor drainage and inadequate aeration for plant roots.

Electrical conductivity (EC) of the medium should not exceed 0.5 mS/cm when the trays are being filled. Repeated application of fertilizer increases salinity in the medium and, if the salt concentration is not reduced periodically through leaching, a toxic level is reached and growth is reduced. If the peat is from an area where ground water is known to be high in sodium, it should be checked for exchangeable sodium (ES). The ES level should not exceed 10 percent.

Seeding

What is to be said about seeding when sophisticated seeding machines are now available? Growers need to moisten the medium sufficiently, before filling the trays. (A fist full of moistened peat should be visibly wet but should not drip when the fist is clenched.) The cavities should be filled uniformly, by tamping, but should not be excessively packe

Following seeding, the minimum amount of grit should be used to cover the seed to keep it in place during watering.

After gritting, the cavities should be saturated with water and the trays should be covered with polyethylene sheeting until germination is completed. If the trays are not covered, the medium dries out and germination is either reduced or occurs over an extended time period.

Light

Next to fertilization, light constitutes the major problem area. Both photoperiod and light intensity are important. Crops of white spruce, for example, have become dormant, prematurely, on account of a short photoperiod. Most growers seed their first crop in January or February and will need to extend natural light (less than 12 hours at 50-55°N latitude) to give a photoperiod of 18 hours, as required. If lights are installed only for prevention of dormancy, savings on electrical power can be realized by cycling the light on for 2 minutes out of every 30 minutes.

Because of their efficiency in photosynthesis, the use of high-pressure sodium lights is recommended. Some contract growers have minimal incandescent lighting to supplement natural light but others have no supplementary lighting at all. For rapid growth, supplementary lighting with an intensity of 7-12 klx (1 klx = 92.85 foot candles = 19.5 $\mu E.m^{-2}.s^{-1}$) is recommended. To prevent dormancy, a minimum of 0.4-1.6 klx, depending on species, is required.

Temperature

Germination of the major prairie conifers (lodgepole pine, jack pine, white spruce and black spruce) is optimum in the 25-28°C range. For growth, there is an overlapping range of day and night temperatures but the optimum for spruce is less than that for pine. For pine, the ranges in day and night temperatures are 22-28°C (optimum 25°C) and 14-19°C (optimum 16°C), respectively. For spruce, acceptable temperature range during daytime is 21-25°C with an optimum of 22°C. At night, the range is 15-20°C with an optimum of 16°C.

Some growers with poly-covered greenhouses were not able to control maximum daytime temperatures in late spring and summer and maintained greenhouse temperatures too warm at night.

Water

Poor water quality and improper application are the chief problems. Electrical conductivity of the water to be used for irrigation should not exceed 0.75 mS/cm. If pH of the water is greater than 7.0, sulphuric acid should be added to lower the pH to 6.0. Water that is high in bicarbonate leaves a white deposit on the foliage of seedlings and should be neutralized with sulphuric acid. Unacceptable salinity and bicarbonate levels are the most common water quality problems.

Many growers apply insufficient water to the seedlings, leaving the lower portion of the cavity too dry. As a result, the seedlings do not thrive. Each cavity should be completely saturated after watering. As a guide, two litres of water should be allowed for a tray of Spencer-Lemaire "Fives", containing 70 cavities, each of 55cm. Normally, the crop is fertilized once per week and watered, as required, during the intervening period.

Fertilizer

The most common problem encountered among growers of containerized seedlings in the prairie provinces is improper fertilization. In most cases, the fertilizer solution applied was much weaker than the grower anticipated but, in one case, the concentration was much higher than expected. The range in concentration was found to be ±5 orders of magnitude. The reason given most often for the discrepancy between "actual" and "expected" concentrations is inaccuracy of the diluter or injector in the watering system. The obvious remedy is to check the diluter/injector and nutrient concentration of the fertilizer solution frequency, i.e. every two weeks. In some cases, a problem with nutrient concentration was not discovered until poor (stunted) growth was noticed well into the growth cycle and a check of the fertilizer solution was made.

After making the fertilizer solution, the strength can be checked as follows: Measure the EC and determine, analytically, the concentration of N, P, and K in the solution. Subsequently, whenever the solution is prepared, e.g. weekly, only the EC needs to be checked. Some growers determine EC but have no idea what reading they should, in fact, be getting. To check EC of the nutrient solution, proceed as follows: Determine A = Reading for the EC of the water supply; B = Reading for the EC of the fertilizer solution. The due to fertilizer is B minus A.

A very simple but indirect method of maintaining a check on the nutrient concentration of the fertilizer solution is to use the colouring imparted by the dye that is incorporated in the fertilizer. The intensity of colour in a standard solution (one in which the concentrations of nitrogen, phosphorus, and potassium are known to be correct, analytically) is compared with that of subsequent samples of freshly prepared solution.

Application of the fertilizer solution should, like that of water, result in completely saturated plugs on completion. Therefore, the solution is applied until excess drips fr the bottom of the tray. Excessive drying between applications of fertilizer solution is not advised because proper re-wetting is time consuming and difficult to achieve.

Quality Control

In order to follow progress of the stock closely, growth curves should be constructed and used for comparison. For each species and seedlot, attributes such as height, root coll diameter, and if desired, dry weight should be measured and recorded at bi-weekly intervals. Each attribute should be plotted against crop age (in weeks) to give a growth curve and each curve is retained for future reference. By comparing the growth curve (progression) of the current crop with one constructed previously for a similar species and seedlot, it will be possible to follow the course of the crop more closely, and to discover potential problems before they become full blown ones.

CONCLUSION

The beginning grower should bear in mind the following principles, if success is to be achieved. Guidelines already prepared for growing containerized tree seedlings should be followed. It is highly likely that the guidelines represent the best methods and procedures, based on research and experience and the grower should benefit from them. Although the environment of a particular facility may not be ideal, it is still important that the grower is aware of the shortcoming and, considering growth requirements, have some concept of its impact on the crop.

The grower should be consistent. Changes in method should be tested on a small scale before full incorporation into the production schedule. The source of suggested changes should be checked or queried to ensure that such changes are compatible with the production system being used. Precipitation of fertilizers from a concentrated stock solution of incompatible products, for example, has resulted from adoption of erroneous advice.

Crop data should be recorded and maintained for future reference. By reviewing the data, the grower will be better informed on the performance of the crop, relative to others that preceded it.

The grower should adopt a policy of checking, double-checking, and cross-checking to ensure that the conditions prescribed for the crop are being met and that the growth, at any given time, is not substandard. For example, during the early months of the year, when natural daylight is less than 15 hours, the grower should be especially vigilant regarding the quality, intensity, and reliability of supplementary lighting. As the old saying goes, "Take care of the small things and the big things will take care of themselves."

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THE PRODUCTION OF GREENHOUSE TRANSPLANTS IN MINI-CELLS AT THE THUNDER BAY FOREST NURSERY

Ron Sherwin
Thunder Bay Forest Nursery

At the Thunder Bay Forest Nursery we have developed a greenhouse transplant system for producing planting stock. The procedure involves starting and growing the crop in a greenhouse and then transplanting it on to the Nursery where its growth continues until harvesting.

The system was developed to replace the traditional 1½ + 1½ stock type. The seedling stage of this stock type was fraught with difficulties as the geographic location and precipitation patterns created some very unfavourable conditions for seedling production. Frost heaving and frost killing compounded the effects of other elements such as birds, rodents, insects, diseases, weeds and mechanical damage, which take a toll on seedlings.

Thus, the original intent in transferring the seedbeds to the greenhouse was to improve reliability in achieving targets. This was effectively accomplished as very predictable loss/survival information permitted accurate inventory control.

This original intent is now somewhat overshadowed by spin-off advantages of the system. Foremost among these advantages is an increase in production efficiency. It now costs less to produce trees. The mechanization of many of the procedures involved and a reduction in tending requirements contribute to this efficiency. We can now optimize the use of valuable seed. Whereas it used to take about a dozen seeds to produce a single shippable tree, it now takes about one and a third. This is particularly advantageous as we increasingly use the more expensive improved seed. Increased production capacity of the Nursery has been realized by using this system. By eliminating outdoor seedbeds and by growing the crop in two years instead of three, nursery compartment space is freed. The stock produced is of superior quality. Trees are taller, their diameter is larger, and their mop-like root system makes this product highly desirable for forest regeneration.

The system we are using is the Techniculture Transplant System that was developed for lettuce production in California by the Castle and Cooke organization. Central to the Techniculture System is the stabilized growing medium. It is a dimensionally stable mix of peat moss and a non-toxic binder. This medium is formed in tapered cavities which are 1.27cm x 4.45cm. Each resultant plug has a formed indentation which is 3.2cm in diameter and 8mm in depth. There are 400 plugs in each tray which has dimensions of 32.1 x 32.1 x 3.8cm.

The Castle and Cooke system possesses many of the features that we were looking for in a transplant system.

The medium is ready to use. There is no necessity to purchase several components such as peat, vermiculite, perlite, wetting agents, etc., which must be accurately blended and mixed in special mixing vats. Also avoided are the filling lines and warehousing requirements of alternate soil medium and tray choices.

Greenhouse space optimized. Each tray has 400 cavities. A typical 9.2 x 42.7 meter greenhouse will hold approximately 1.2M trees in a single crop. With three crops per year, one house will produce 3.6M trees.

The design and configuration are culturally correct. The plug shape can accommodate the tap root of coniferous seedlings. The indentation/cavity within the plug permits ideal seed placement for even germination and growth.

The system lends itself to mechanization. Since plugs retain their conformity they can be handled mechanically. The square dimensions of the trays permit easier alignment at all stages of production and handling.

The concept is a "system". all components are readily available to assemble a system: trays, seeder, benching, handling, transplanting.

Trays are filled with the rubber soil (which is a patented product) at the plant in California and are shipped to us via commercial carrier. They are contained in a plastic wrapped pallet which can be handled by forklift for storage or for immediate seeding. Since the medium is moist, the plastic wrap is essential to prevent drying and shrinking of the plugs. in most cases trays are seeded within a short time of receipt, we have on occasion stored them for several months without any detrimental effects.

We do our seeding with a BCC seeder which was purchased from Sweden. With this high capacity, high precision seeder, we can sow up to 360 trays per hour with 98.5% of the trays receiving one seed per cavity. We have mounted the machine on caster wheels which allows us the mobility to set up the seeding operation at the entrance to each greenhouse. Seeded trays are transferred to the greenhouse with a conveyor and manually set on to the Y-bar benching system. the Y-bar permits sliding the trays into or out of position during loading or unloading. it also allows cavity drainage and air pruning of protruding roots.

Immediately after loading the greenhouse, conditions suitable for germination are established. Temperature is maintained at 25-27°C and irrigation is applied at levels and intervals to enhance germination but prevent damping-off and other detrimental effects. Energy curtains are drawn as appropriate in order to maintain a more constant environment: during the day to prevent high temperatures and at night to conserve energy and prevent very low temperatures.

After germination, greenhouse temperatures are maintained at 20-25°C and fertilization begins about five days after the seed caps have dropped off the seedlings. By this time lateral roots have begun to emerge. Fertilizer is applied at every irrigation during the active growing period. "Starter" fertilizer is applied at 50 ppm for the first two weeks. "Grower" fertilizer is applied at 100 ppm for the remainder of the active growing period and "finisher" fertilizer is applied at 40 ppm during the conditioning period.

Three crops are grown in the greenhouses each year. The first, which is grown from mid-march until the end of May, is moved into a cold frame at that time for a brief acclimatization period prior to transplanting. The second crop is grown from early June until mid-August when it is moved into the cold frame for maintenance and natural conditioning. The third and final crop is actively grown in the greenhouse from mid-August until late October after which light and temperatures are gradually reduced to induce dormancy and frost hardiness.

For the March crop no supplemental light is required, however an eighteen hour photoperiod is provided for the late summer crops in order to prevent premature bud set.

The spring crop, after a period of acclimatization, is immediately transplanted onto the Nursery. The two summer crops, after achieving the desired index of injury (from frost) levels, are placed in boxes in late November and held in refrigerated storage at -2 to -4°C until the following May when they are thawed and transplanted.

The concept for the transplanter which we are using was also developed by the Castle and Cooke organization. Their machine was developed for lettuce crops which have a much different bed and spacing configuration. Hence an entirely new machine had to be designed. The result is a diesel powered, self propelled four wheel hydrostatically driven short turning carrier unit which supports eight high speed planting heads that can extract and transplant trees from trays that are inserted into the mechanism. An operator drives the machine while two feeders remove trays from large cartridges and place them into sliders leading to the extractor heads. Their next task is to return empty trays to the cartridge.

Cartridges are filled with current or overwintered trays at the cold frame and transferred to the field by truck. They are placed onto and removed from the platform of the transplanter with a fork lift.

The transplanter has the capacity to plant about 160,000 trees per hour. However, with loading time, the shift output ranges from 500,000 to 600,000 trees. Thus to transplant our target of about 16.0M black spruce it takes about 20 days.

The development of this production methodology began at the Thunder Bay Forest Nursery in 1984. Small trials were conducted during the first few years to test the biological feasibility of the system. Levels of production were then expanded to test the logistics of the system. In 1988 the method became operational at the Nursery and this year (1990) we have no outdoor black spruce seedbeds at all at our Nursery. To date we have transplanted about 40.0 million trees in the manner described in this presentation.

PFRA SHELTERBELT CENTRE 1990 TREE DISTRIBUTION REPORT*

Submitted to: Prairie Tree Nursery Association Meeting
September 10, 11, 12, 1990
Pineland Provincial Forestry Nursery
Hadashville, Manitoba

Tree Distribution by Species

Deciduous Trees	
Japanese Elm	550
Green Ash	1,164,225
Siberian Elm	105,775
Manitoba Maple	76,850
Bur Oak	8,175
American Elm	50
Poplar - Northwest	27,880
- Walker	181,430
- Assiniboine	18,870
- Mixed	3,100
Willow - Laurel	30,620
- Acute	133,070
- Silverleaf	22,320
- Chermisina	260
- Mixed	6,130
- Hardwood Cuttings	18,810
Deciduous Shrubs	
Caragana	6,076,700
Villosa Lilac	979,775
Buffaloberry	115,150
Chokecherry	385,350
Russian Olive	17,800
Red Elder	10,450
Hedge Rose	44,425
Dogwood	61,500
Sea Buckthorn	57,225
Honeysuckle	10,900
Siberian Crab	6,900
Ussurian Pear	3,650
Saskatoon	2,475
Snowberry	8,675
Hawthorn	1,675
Coniferous Trees	
Russian Scots Pine	3,900
White Spruce	138,840
Scots Pine	86,140
Siberian Larch	8,800
Colorado Spruce	411,790
Larch Container	3,470
2-4 Colorado Spruce	39,670
TOTAL	10,273,375

*Above figures are based on preliminary report.

Tree Utilization & Distribution by Province

Use	**Saskatchewan**	**Manitoba**	**Other**	**Total**	**% of Total Distribution**
Farmstead	2,514,570	867,245	14.280	3,396,095	33
Field	4,240,775	920,385	41,550	5,202,710	51
Wildlife	284,635	49,010	7,650	341,295	3
Other (replacement, Small Holdings, Roadside, Charitable Organization, etc.)	629,835	361,470	341.970	1,333,275	13
Total	7,669,815	2,198,110	405,450	10,273,375	
% of Total	75	21	4		

APPENDIX 1

Sep. 10/90

PRAIRIE TREE NURSERY ASSOCIATION MEETING
AGENDA
SEPTEMBER 10 - 12, 1990
FALCON LAKE, MANITOBA
&
PINELAND PROVINCIAL FOREST NURSERY, HADASHVILLE, MANITOBA

September 10

19:00 - 22:00	Ice breaker, snacks and pre-registration at the Falcon Lake Resort and Club, Falcon Lake, Manitoba

September 11

08:00 - 08:15	Continued Registration
08:15 - 09:00	Call to order, Introductory Remarks Richard Cameron, Manager Pineland Provincial Forest Nursery Opening Address Bryan Oborne, Executive Assistant Sustainable Development Co-Ordination Unit Moderator - Richard Lepage
09:00 - 09:30	"Development of a Land Prep Program at Pineland Nursery" Vic Timmer, Professor University of Toronto
09:30 - 10:00	"Implementation of the Land Prep Program at Pineland Nursery" Wendy Kozmak, Bareroot Supervisor Pineland Provincial Forest Nursery
10:00 - 10:15	Coffee
10:15 - 10:40	"Overwintering Container Stock at Pineland Nursery" Richard Lepage, Greenhouse Supervisor Pineland Provincial Forest Nursery
10:40 - 11:10	"Manitoba's Tree Improvement Program" John Dojack, Silviculture Forester Manitoba Natural Resources

11:10 - 11:30	"Preliminary Results of Infra-red Heating Trials at Clearwater Nursery" Shane Tornblom, Manager Clearwater Provincial Forest Nursery
11:45	Board bus for Pineland Nursery
12:20 - 13:20	Catered Lunch at Pineland Nursery
13:30 - 17:00	Tour of Pineland Provincial Forest Nursery
17:00	Barbecue at Pineland Nursery Poster Displays Evening Activities: Horseshoes, Ping Pong and Cribbage
20:00	Van(s) will depart from the nursery to Falcon Lake Resort and Club every hour for those wishing to return.

September 12

08:15 - 08:30	Business Meeting Chaired by Richard Cameron, Manager Pineland Provincial Forest Nursery Tree Nursery personnel from the prairies requested to attend
08:30 - 08:50	Call to Order, Housekeeping Items Richard Lepage, Moderator
08:50 - 09:15	"Container Production of Siberian Larch" Dan Walker, Propagation & Tree Improvement Technician Prairie Farm Rehabilitation Association
09:15 - 09:35	"Monitoring Stock Quality Using RGC at Pineland Nursery" Wendy Kozmak, Bareroot Supervisor Pineland Provincial Forest Nursery
09:35 - 10:00	"Stock Performance in Field Conditions, Where Do We Go From Here" Vince Keenan, Forest Renewal Supervisor Abitibi-Price Inc.
10:00 - 10:15	Coffee

10:15 - 10:45	"The Effects of Heat Stress on Container Seedling Production" Steve Colombo, Research Scientist Ontario Forest Research Institute
10:45 - 11:10	"Options for Rearing Quality Container Seedlings" Al Nanka, Tree Improvement Specialist Forestry Canada
11:10 - 11:40	"Ontario Nursery Inventory Program" Thom McDonough, Nursery Stock Culture Specialist Ontario Ministry of Natural Resources
11:40 - 12:00	"Cool Day/Warm Night Conditioning of Container Stock" John Thorpe, Superintendent Clearwater Provincial Forest Nursery
12:00 - 13:00	Lunch
13:00 - 13:30	"SIAMM - Irrigation Model at Dryden Tree Nursery" J.M. McIntyre, Superintendent Dryden Tree Nursery
13:30 - 14:00	"Quality Control in Growing Containerized Seedlings" Ivor Edwards, Nursery Management & Tree Improvement Project Leader Forestry Canada
14:00 - 14:30	"Greenhouse Transplants in Mini-Cells at Thunder Bay Forest Nursery" Ron Sherwin, Operations Manager Thunder Bay Forest Nursery
14:30	Coffee and Disperse

APPENDIX 2

REGISTRATION LIST

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September 10, 11, and 12, 1990

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APPENDIX 3

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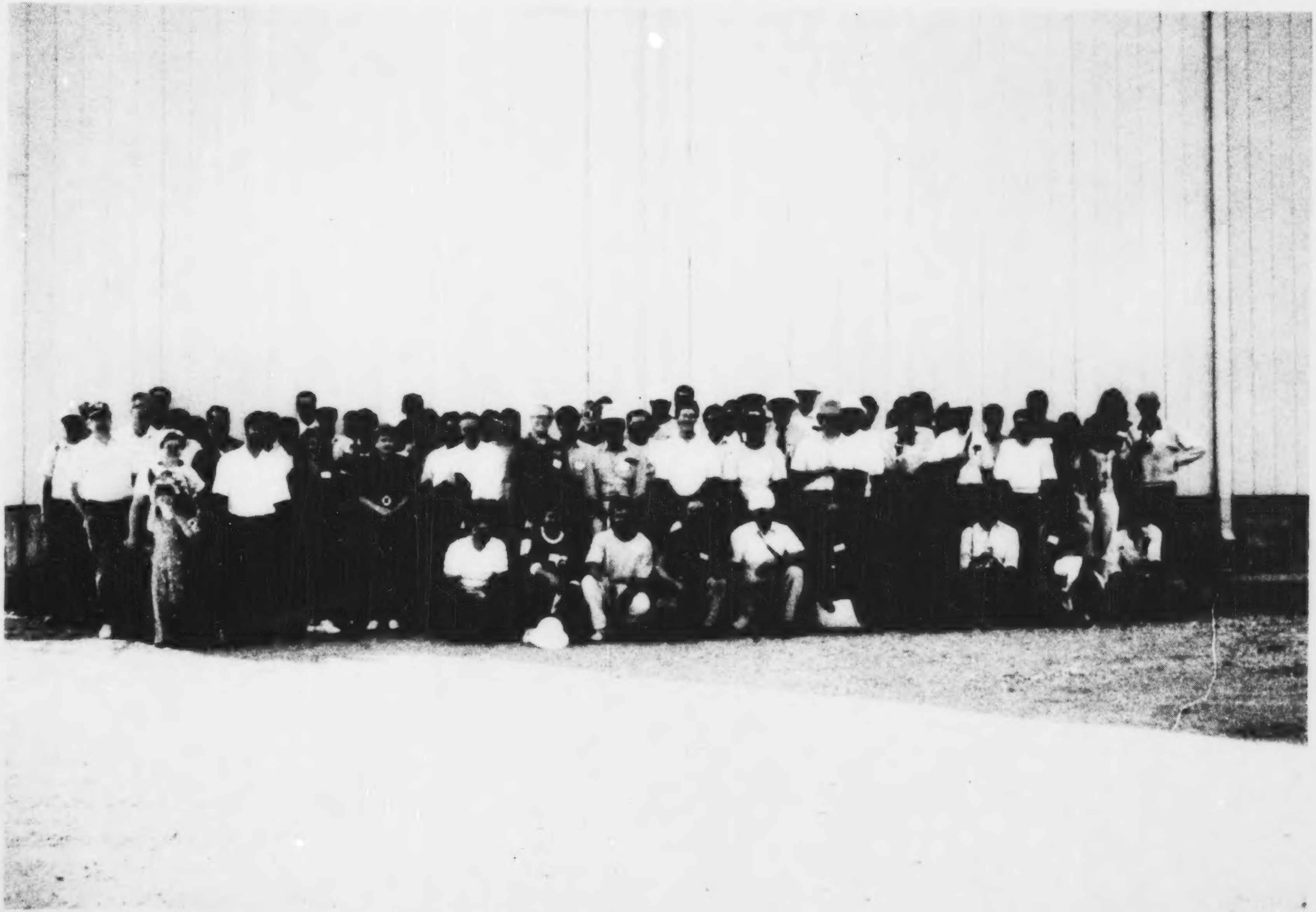

Participants at the 1990 Prairie Tree Nursery Association Conference.